Section 3. EOS Ground System Component Descriptions

The EGS and EOSDIS architecture and physical configurations have been designed on the basis of several key drivers so that EOSDIS will perform the following functions or have the following attributes:

- Support new modes of research and facilitate synergistic interactions between data from the EOS instruments and simulations with models developed by EOS researchers.
- Archive and provide access (interoperability) to usable scientific information to the geophysical, biogeochemical, ecological, and interdisciplinary communities, to be used by a wide spectrum of scientists and the public during the life of the EOS mission.
- Archive and provide access to standard, reliable data products that are essential to distinguish natural and anthropogenic variations so that the scientific community has access to independent measurements to validate and drive models of processes on local, regional, and global scales.
- Perform the command and control of the EOS instruments and the spacecraft to control the recoveries of data and provide the capability to monitor and react to the health and safety of the spacecraft systems and instruments.
- Be a user-driven (friendly) system that assures low-level system operations and configurations that are transparent to the user.
- Be a distributed system that incorporates display-oriented archives.
- Incorporate evolutionary methods for providing long-term archives and access to these archives.
- Optimize the use of commercial-off-the-shelf (COTS) components to provide use-tested, easily interchangeable, upgradable components and to reduce development costs.
- Provide interoperability among individual EOS systems, within the SDPS components, and among SDPS clients and services.
- Provide interoperability between the EOSDIS Core System (ECS) and the ASTER GDS that allows an EOSDIS user or the ASTER GDS user to view the data holdings and order production data from the other system.
- Provide interoperability between ECS and Version 0 to allow an ECS or Version 0 user to search the data holdings and order data from the other system.

- Provide interoperability between EOSDIS and other systems such as GCDIS or other holdings.

The following sections describe the EGS components assembled to meet these requirements. Figure 3-1 shows the context for EGS, EOSDIS, and EOSDIS components. Section 3.1 describes the SDPS, followed by sections on mission operations, data capture, communications, test systems, and ground stations.

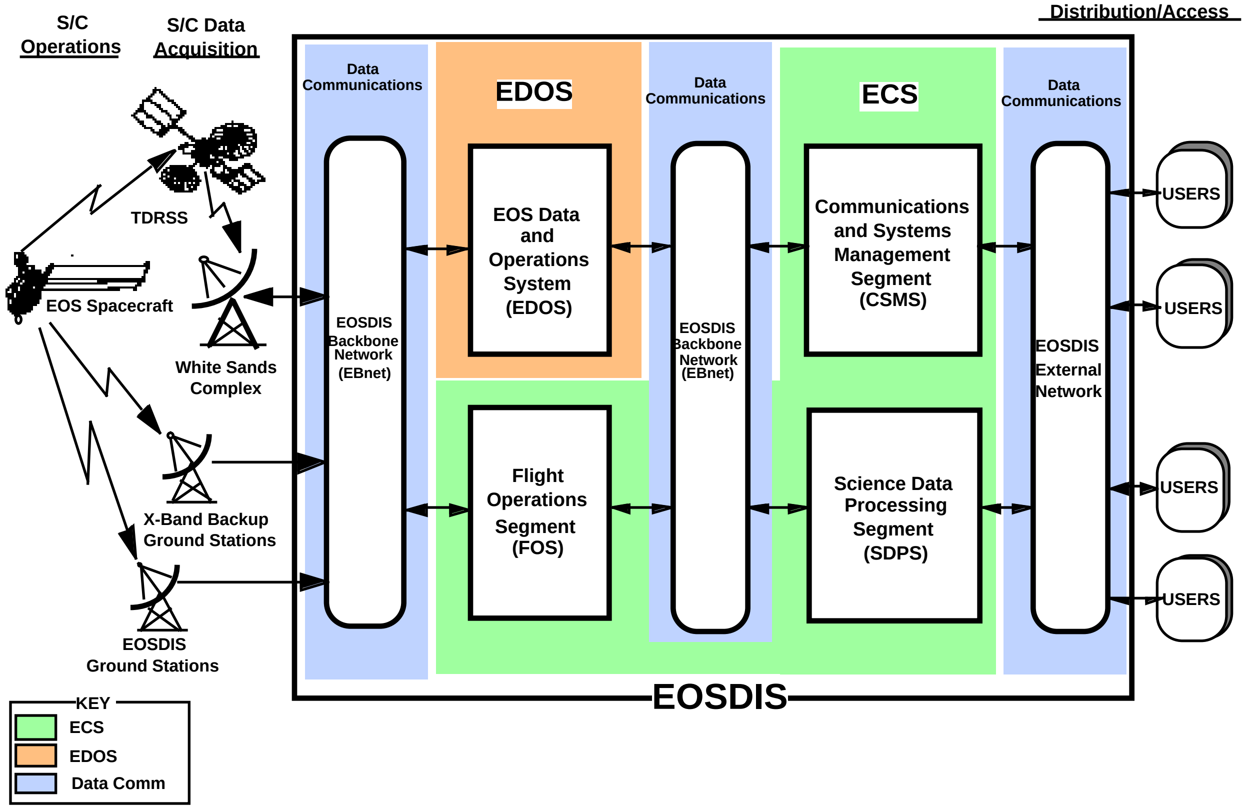

Figure 3-1. Context for EOSDIS in EGS

3.1 Science Data Processing

The distributed network of DAACs is the main EOSDIS institution for performing science operations. The DAACs provide many services, including ingest of Level 0 and ancillary data and products; data management, archive, catalog, and distribution; execution of science software for product generation; user support services; and access, search, and retrieval of EOS and non-EOS NASA Earth science data and all supporting information. DAACs respond to science priorities and guidance and cooperate with other DAACs as integral parts of EOSDIS.

Science data processing and operations may occur at many affiliated and other data centers, universities, and laboratories, in addition to taking place at the DAACs. Although accomplished in a less formal manner, the same approach to implementation of these capabilities is followed: existing Earth science facilities and operations are augmented with

EOSDIS tools and components to achieve a broader capability to conduct science operations. In comparison to the DAACs, these other sites typically receive only toolkits or parts of subsystems rather than complete EOSDIS hardware/software systems.

The requirements for the EOSDIS science data processing and operations capabilities were originally expressed in terms of two segments of the ECS implementation contract, as described in Appendix C. These two segments are the CSMS¾ whose requirements are principally discussed in Sections 3.4 (Data Communications) and 3.5 (System Monitoring and Coordination Center)¾ and the SDPS, which is addressed in this section. The implementation of these requirements has subsequently followed a functional approach, with the results depicted in Figure 3-2. In this context, the seven configuration items in the middle of Figure 3-2 constitute the SDPS, whereas the management subsystem (MSS) and communications subsystem (CSS) functions at the top and bottom of the figure, respectively, combine to fulfill the CSMS requirement.

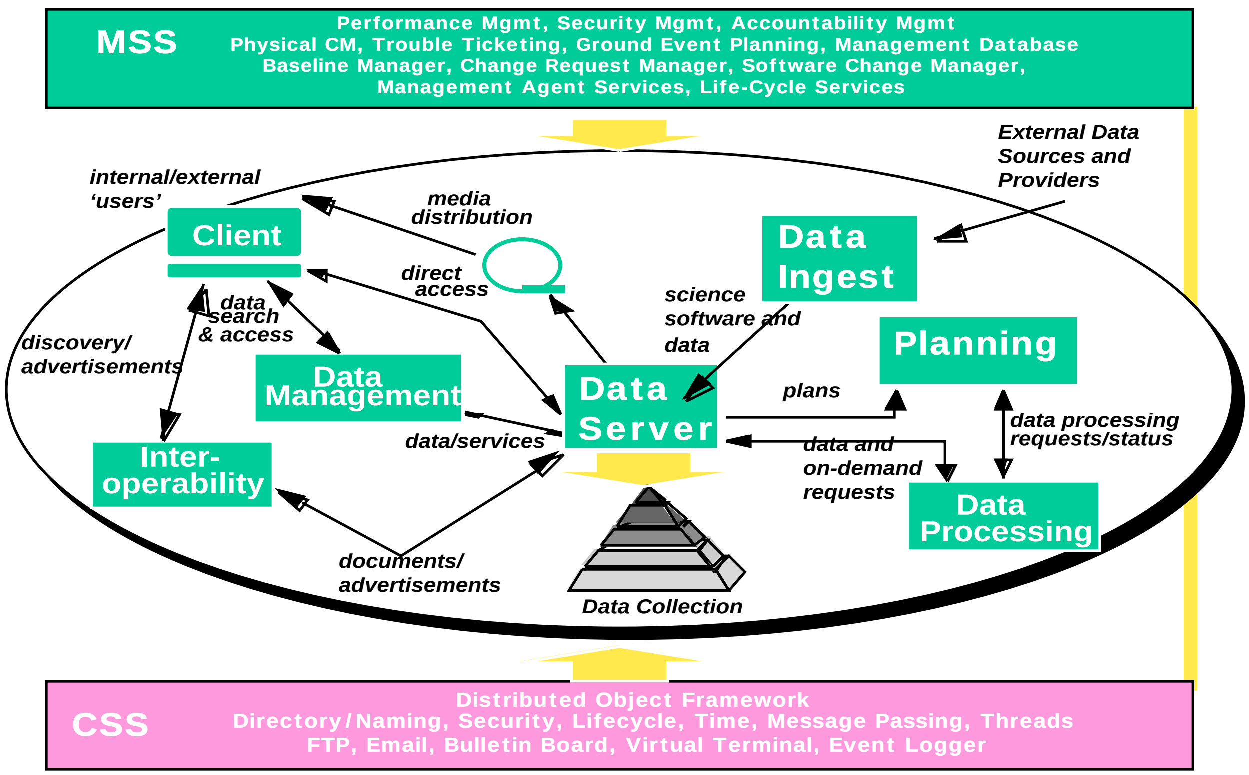

Figure 3-2. EOSDIS Science Data Processing and Operations Context

The SDPS provides a set of data processing and data distribution elements for science data and information systems at the DAACs. The SDPS provides ingest of Level 0 and ancillary data, data management, and archival. The SDPS also provides the processing environment for the execution of science software. The SDPS is the primary user interface to other parts of EOSDIS, providing the science users with the capability to identify and retrieve science data from any of the DAACs. The DAACs themselves provide the facilities for the SDPS functions, along with the management and operations support. The SDPS is designed consistent with the evolving Open Distributed Processing standard.

The SDPS receives, processes, archives, and manages all data from EOS and EOS-related flight missions. It provides support to the user community in accessing the data as well as products resulting from research activities that utilize this data. The SDPS also promotes, through advertisement services, the effective utilization and exchange of data within the user community. It plays a central role in providing the science community with the proper infrastructure for development, experimental usage, and quality checking of new Earth science algorithms.

The SDPS was originally defined as three elements at the requirements level: Product Generation System (PGS), Data Archive and Distribution System (DADS), and Information Management System (IMS). The EOSDIS design and implementation approach allocates these requirements over the seven SDPS and two CSMS configuration items (CIs), with multiple Computer Software Configuration Items (CSCIs) representing a functional approach. These CIs are Planning, Data Processing, Ingest, Data Server, Interoperability, Data Management, and Client subsystems for the SDPS and Systems Management and Communications subsystems for the CSMS. Table 3-1 identifies the involvement of nine subsystems in the three elements. Over time, the use of the logical distinction for PGS and DADS has been greatly reduced, whereas the IMS expression is still frequently used. The following subsections discuss seven CIs of the SDPS.

3.1.1 Planning Subsystem

The Planning subsystem plans and manages the production of standard science products from the EOS telemetry and ancillary data in response to production requests received from users. It is responsible for supporting operation staff in managing the data production activities at a site. Figure 3-3 shows the Planning and Data Processing subsystems in context. The Planning subsystem assists the operations staff in performing two major functions: defining the data processing tasks to be performed at a site and generating efficient plans for scheduling those tasks.

In addition, the Planning subsystem is responsible for coordinating the production with the Data Server and Data Processing subsystems to achieve a highly automated production system.

Table 3-1. Identification of Implementation Subsystems With Original SDPS Elements

	SDPS Elements		
Implementation Subsystems	Information Management System	Product Generation System	Data Archive and Distribution System
Planning		✶	
Processing		✶	
Ingest		✶	✶
Server	✶	✶	✶
Interoperability	✶		
Data Management	✶		✶
Client	✶		
Systems Management (MSS)	✶	✶	✶
Communications (CSS)	✶		✶

The Planning subsystem obtains, stores, and uses information that is referred to as Product Generation Executive (PGE) Profiles. PGE Profiles include information on the PGE executable, the input data type(s) required, the output data type(s) generated, and the PGE resource requirements¾ hardware platform, memory, disk storage, etc.

The primary interface of the Planning subsystem with the Data Processing subsystem is to describe the PGEs that need to be run to fulfill the production goals. A Data Processing Request (DPR) describes a run of a PGE to the Data Processing subsystem. It describes the specific input granules, output filenames, and run-time parameters for a PGE, as well as dependencies and target run times. The Data Processing subsystem provides status and processing completion information to the Planning subsystem.

The planning user interface provides a means of human interaction with the Planning subsystem. Through this interface, a user can enter production requests. A production request describes an order for data that is to be produced by the Data Processing subsystem. Production requests may signify the need for processing of new data (standard

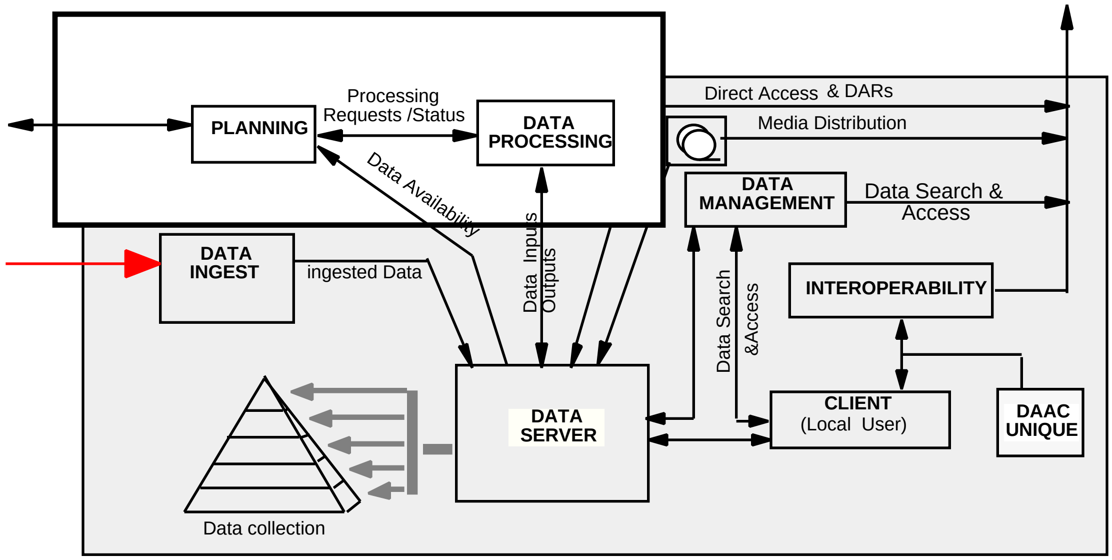

Figure 3-3. Planning and Data Processing Subsystems

production requests, a.k.a. standing orders) or the need for the reprocessing of data (reprocessing production requests). The Planning subsystem takes these production requests and uses the PGE profile information to work out the DPRs that will be required to fulfill the production request. For large reprocessing requests (e.g., 6 months of data), DPRs are generated and ordered on the basis of operator-chosen rules. The planning user interface is also used to issue commands to initiate plan creation, plan activation, and plan cancellation, as well as to provide reports/status of progress within a plan. Additional user interfaces will be provided to inform the system of ground events and external events that can impact processing resources or data. To aid in handling inter-DAAC data dependencies, the planning user interface will also provide the ability to display another DAAC's plan at the local site. The data dependencies between the two sites will be identified by the system.

The Planning subsystem queries the data server holdings for existence of data required for processing. If the data exist, the data server responds with granule information (identification, metadata, and location). The data server also provides the subscription services needed by Planning to determine when new data are available for processing. The operator can use a Planning subsystem utility to generate the subscriptions to be entered into the data server. The data server sends a notification when data that fulfill the subscription are inserted into the data server. Subscriptions are also submitted on data availability schedules and FOS schedules so plans can be based on more accurate predictions of when data will arrive.

In addition, on-demand production requests (ODPRs) are received from the data server. ODPRs are checked against predetermined acceptance criteria as well as resource usage thresholds. If an OPDR fails any of the acceptance criteria, it is rejected, and a notification is made to the requester describing the reason for rejection. If the ODPR is accepted but exceeds a resource usage threshold, it is passed into the regular planning stream and treated as any other standard or reprocessing request. ODPRs that do not exceed the resource usage threshold are sent directly to the Data Processing subsystem.

The Ingest subsystem also provides a subscription service (via the Ingest Data Server) for notification of the arrival of Level 0 data from the Sensor Data Processing Facility (SDPF) and EDOS. The Advertising CSCI within the subsystem provides the advertisement data that is required by the Planning subsystem to generate a subscription.

The Planning subsystem uses the Document Data Server within the Data Server subsystem to store production plans. The Document Data Server then make those plans available to the user community.

The Planning subsystem also has an interface to the systems management subsystem (MSS). The Planning subsystem is responsible for sending MSS fault management data, accounting data, security data, and performance data. The Planning subsystem exchanges mode management information and receives event notifications from the MSS.

3.1.2 Data Processing Subsystem

The Data Processing subsystem generates the science products and provides the processing environment for this function. These responsibilities can be divided into the following general functional areas:

1. Managing the generation of Data Products and the operational environment used to produce these products.
2. Providing an algorithm integration and test environment for the introduction of science software into the EOSDIS environment.
3. Providing a quality assurance (QA) environment for testing the quality of data products.

The Data Processing subsystem supports these functional areas through the following mechanisms:

a. Provides a batch processing environment to support the generation of data products. It manages, queue, and executes DPRs on the processing resources at a provider site. A DPR can be defined as one processing job. Each DPR encapsulates all of the information needed to execute this processing job. DPRs are submitted from the Planning subsystem; which in turn has been triggered by the arrival of data or internally through Planning itself (e.g., reprocessing). DPRs use PGEs to perform this processing. PGEs result from the integration and test of delivered science algorithms and also user-specific methods into the subsystem. PGEs are encapsulated in the ECS environment through the SDP Toolkit. The Data Processing subsystem also provides the operational interfaces needed to monitor the execution of the science software (PGEs).

b. Supports the execution of science algorithms through the SDP Toolkit, which is a set of tools developed to standardize and provide a common interface to the EOSDIS environment for each science algorithm.

c. Supports the preliminary processing of data sets, i.e., Level 0 data products, required to put the science algorithms in the proper format for use.

d. Provides the algorithm integration and test environment used to integrate new science algorithms, new versions of existing science algorithms, and user methods into the EOSDIS environment. The algorithm or method is acquired by the system through an ingest client, which reflects local site policies on the acceptance of software for integration. Once acquired, the algorithm/method and its associated data files (test, calibration, etc.) are registered in the local site configuration management (CM) system as part of the archival by the Data Server subsystem.

e. Provides the DAAC QA environment that DAAC personnel use to validate data products. All data products, those both produced by and input to a submitted job, can be examined by DAAC personal to verify that their content meets quality standards.

The following paragraphs describe the key interfaces for the Data Processing subsystem.

a. The Planning interface is responsible for determining what processing activities are required to generate the data products as specified in a standard production request. These processing activities and associated information are defined and delivered as DPRs to the Data Processing subsystem. One production request may result in one or more DPRs being sent to the Data Processing subsystem. After the receipt of a DPR, the Data Processing subsystem delivers processing status to Planning when requested. The Data Processing subsystem also provides an unrelated offline activity, information used to plan the execution of a PGE. This information is determined by the Algorithm Integration and Test services and is provided to Planning through the adding of data to the SDPS Database.

b. The data server interface is for requesting access to data required as an input to a PGE and for requesting that generated output data be transferred to the data server. The data server is also used to archive PGEs and associated data that require staging.

c. The Ingest interface is for requesting access to Level 0 data to be preprocessed before being input to a PGE.

d. The MSS/local system management (LSM) interface provides access to common ECS system management services and application programming interfaces (APIs) to pass accounting and CM information.

3.1.3 Data Ingest Subsystem

The Data Ingest subsystem contains a collection of hardware and software that supports the ingest of data into ECS repositories on a routine and ad hoc basis and triggers subsequent archiving and/or processing of the data. Figure 3-4 shows the Data Ingest and Data Server subsystems in context. The Ingest subsystem configuration must be flexible to support a variety of data formats and structures, external interfaces, and ad hoc ingest tasks. Data processing and storage functions to be performed by the Ingest subsystem and ingest clients vary according to attributes of the ingested data such as data type, data format, and the level to which the ingested data has been processed.

From a software perspective, the Ingest subsystem is organized into a collection of tools from which those required for a specific situation can be configured. The resultant configuration is called an ingest client. Ingest clients may exist in a static configuration to service a routine external interface, or they may be specially configured and exist only for the duration of a specific ad hoc ingest task. The ingest clients provide a single virtual interface point for the receipt of all external data to be archived within the SDPS. Individual ingest clients are established to support each unique interface, allowing the interface parameters to be modified as interface and mission requirements evolve. The ingest clients perform ingest data preprocessing, metadata validation, and metadata extraction on any incoming data as required.

Data is staged to one of two areas depending on the data level, data type, and other data set specific characteristics, as follows:

- Level 0 data from ongoing missions is staged to the Ingest subsystem working storage area, where the data is ingested and stored in the Level 0 rolling store. The staged data is also accessible by the SDPS Processing subsystem for that data that must be processed to higher levels.
- Level 1a-4 data is staged directly to the working storage area in the Data Server subsystem. Ingest client functionality such as quality checking and reading of metadata is performed on these data on the Data Server subsystem processor hardware. The data server then archives the data in the logical and physical data server to which the particular data has been assigned.

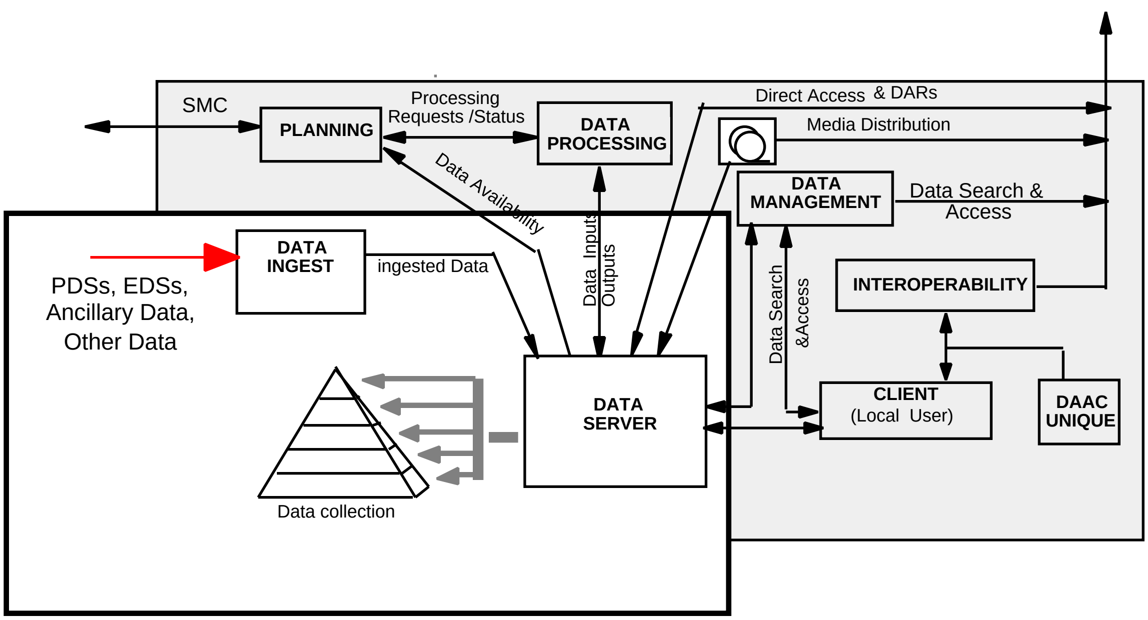

Figure 3-4. Data Ingest and Data Server Subsystems

The hardware components of the Ingest subsystem are similar to those of the Data Server subsystem but are specialized to meet the ingest requirements at a given site. Specialized forms of ingest clients may be incorporated into site-unique architectures, and additional processing hardware may also be incorporated at those sites where special transformations must be accomplished on ingest data sets.

The Ingest subsystem must be capable of accepting data from a variety of sources, including both electronic network interfaces and hard media. Early interface testing is performed at Interim Release-1 (IR-1) for interfaces at the SDPF, TSDIS, and the NOAA ADC. Release A interfaces include the SDPF, TSDIS, NOAA ADCs (NESDIS and the GDAO), the science computing facilities (SCFs) (for algorithm delivery), the data server subsystem (for archiving), science users, clients (operations staff), Version 0 DAACs, and other DAACs. Early interface testing is performed at Release A for the EDOS, Landsat-7, and EOC interfaces. Release B interfaces include the SDPF, TSDIS, NOAA ADC, the SCFs (for algorithm delivery), the Data Server subsystem (for archiving), science users, clients (operations staff), Version 0 DAACs, and other DAACs. Early interface testing is performed at Release B for EDOS, the Landsat Processing System (LPS), and EOC interfaces. The EDOS, LPS, and EOC interfaces are fully functional at Release B. Interfaces are added at Release B for the Landsat IGSs and Image Assessment System (IAS), ASTER GDS, Release B SCFs, Flight Dynamics Facility (FDF), SeaWinds, SAGE III, ALT/RADAR, ACRIM, and DAAC-unique interfaces (including ERS, JERS, and RADARSAT at the Alaska SAR Facility [ASF]). Additional interfaces are planned to be implemented in future releases.

The following assumptions have been made regarding the characteristics of the data to be ingested:

- EDOS, the spacecraft data capture and distribution system discussed in Section 3.3, and SDPF (which is a NASA institutional system used for data capture for the TRMM mission) each generate production data sets (PDSs), which are transferred when the data set is complete. EDOS has stated that PDSs will be based on time and/or size (not granule or orbit). Each transferred file contains only one Application Process ID (APID). SDPF has stated that the data will be transferred once per 24-hour period.

- Receipt and processing of products from other sources is assumed to be random but largely continuous over a 24-hour period. Ingest subsystem resources are sized to handle predictable peak loads.

Main drivers for the Ingest subsystem design are

- The high reliability required for Level 0 data ingest

- The required extensibility of the ingest client implementation to future external interfaces

- The demands imposed on ingest by the migration of Version 0 data from DAAC repositories external to ECS

The Ingest subsystem design incorporates the measures described in the following in response to the above drivers.

1. The need for high reliability to support the function of Level 0 science data ingest was resolved by the logical and physical separation of the Ingest subsystem (Level 0) data server from the other data servers. The ingest of Level 0 data has a very high priority and must be supported with high component reliability and availability. Maintaining this level of reliability, maintainability, and availability (RMA) throughout the entire SDPS would be prohibitively expensive. Separating a high RMA ingest complement of hardware and software from other SDPS functions allows each subsystem within SDPS to support only the level of RMA necessary to perform its required functions.

2. The need for future extensibility was resolved by separating the ingest processing component from the associated data server component and providing template interface software that may be reused as new interfaces are added or old interfaces are modified. The external interfaces to be supported by the ingest clients change over time as spacecraft and instruments are added and removed. Each external interface must potentially be supported with a different data transfer mechanism, format conversion, quality checking, metadata definition, and other attributes unique to that data. Separating the performance of these functions from the Level 0 data repository component minimizes or eliminates changes to the data server configuration as mission requirements change.

3. In addition, each new or modified external interface may require custom interface software to facilitate the data transfer process. The long-term EOS program expects to add large numbers of new interfaces over time. The Ingest subsystem software is designed in a modular fashion to minimize the development effort required for new or modified interfaces.

4. The volume and complexity of data provided from the Version 0 facilities to the ECS for archival are critical design drivers for the ECS Ingest subsystem. Over 600 data products have been identified, ranging in volume from megabytes to hundreds of gigabytes. Total volume is on the order of dozens of terabytes. Many of the data products are stored in some form of Hierarchical Data Format (HDF); however, many more products are stored in other formats. The Ingest subsystem software is designed to generalize the mechanism by which data is routinely stored within the SDPS, given a set of standalone tools used to prepare Version 0 data. Version 0 "data preparation" includes retrieval from Version 0 specific hard media; conversion to EOS-HDF, where required; and extraction of standard metadata.

3.1.4 Data Server Subsystem

This subsystem is responsible for storing Earth science and related data in a persistent fashion, providing search and retrieval access to this data, and supporting the administration of the data and the supporting hardware devices and software products. As part of its retrieval function, the subsystem also provides for the distribution of data electronically or on physical media. Characteristics of the Data Server subsystem are as follows:

- Advertises its data types and the services it provides against this data with the Interoperability Services.

- Stores data received through ingest by the Ingest subsystem or resulting from processing in the Data Processing subsystem, as well as historic data from FOS.
- May issue production requests into the Planning subsystem and acquisition requests into a DAR processing subsystem as a result of data requests issued by data server clients. It also supports the Planning subsystem by storing data availability schedules.
- Accepts data search and access requests from any subsystem or other segment provided that they are directed specifically at the data objects managed by the given instance of the Data Server subsystem. (All other search and access requests are funneled through the distribution information manager (DIM) and/or local information manager (LIM) services of the Data Management subsystem.)
- Provides the data resulting from these access requests through electronic transfer or on physical media. The subsystem can also provide references to this data in the Universal Reference format instead.
- Interfaces with MSS/LSM and the System Monitoring and Coordination Center (SMC) to provide subsystem status and log information.

3.1.5 Client Subsystem

The client subsystem provides a collection of components through which users access the services and data available in ECS and other systems interoperable with ECS. Figure 3-5 shows the Client, Interoperability, and Data Management subsystems in context. The Client subsystem also includes the services needed to interface an application (e.g., a science algorithm) with ECS, e.g., for data access or to make use of ECS-provided toolkits.

Accessed services can be remote (i.e., via wide area network [WAN] to other sites) and local (e.g., to a database manager at the user's site).

A primary role of this subsystem is to give the users efficient access to the ECS data products, providing them with all the information and tools to search, locate, select, and order products required to perform their science investigations. These products may be stored in the archives or may entail higher level processing of an archived product or placing an acquisition and processing request. The subsystem also assists the users in locating and ordering non-ECS data from ADCs and other cooperating data centers.

The Client subsystem is envisioned as a "one-stop shopping" capability for EOSDIS users, employing a standardized user interface. Capabilities include a data dictionary on line and guide features that facilitate data and product ordering. Data can be accessed via multiple parameters such as granule notation, time, and geographic location.

In addition to providing users with information on data products , the Client subsystem also provides access to other information the users require. This includes general mission information, algorithm descriptions, accounting information, and the status of any requests that the scientists have submitted to the system. The sources and, in some cases, the maintenance of these information bases is distributed among the other ECS components, including the SMC, the EOC, and the DAACs, as well as the EOS scientists themselves.

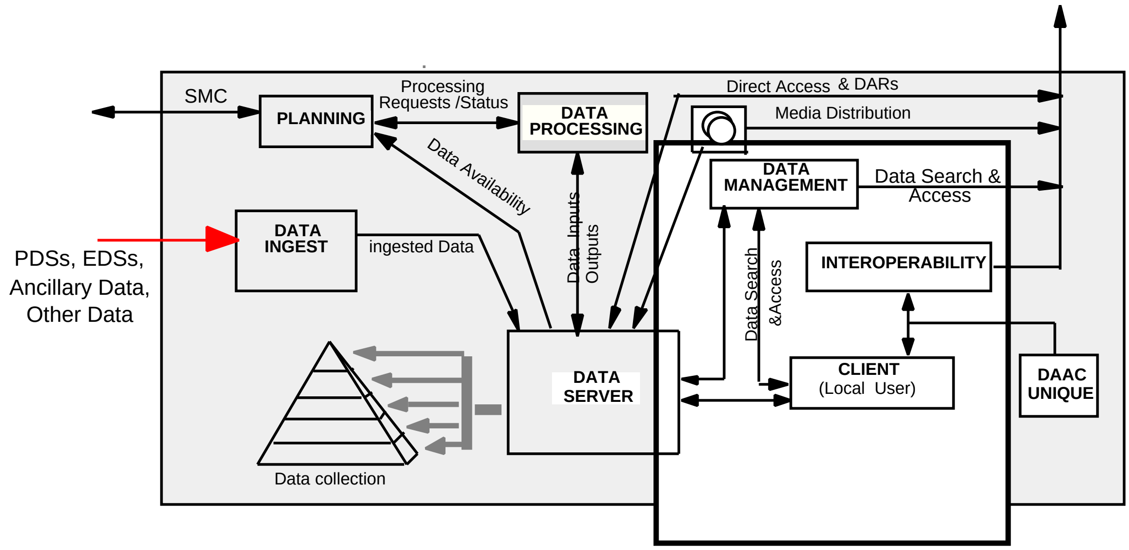

Figure 3-5. Client, Interoperability, and Data Management Subsystem

The functional capabilities that the Client subsystem provides have been aggregated into the following service categories:

- System Access and User Registration
- Information Management

  The functional capabilities that the Client subsystem provides have been aggregated into the following service categories:

- Information Search and Browse
- Archival Product Requests
- Data Processing Requests
- Data Acquisition Planning and Request Submittal
- Data Request Routing and Tracking
- Cost Estimation and Account Status Interface
- Toolkit Services
- Access to Communication Services
- Statistics Collection for Local Systems Management

Client subsystem components fall into one of the following general categories:

- An intuitive desktop manager, which manages desktop objects (files) in the user's local file space and which represents applications and data in the domain of the client
- Graphical and command line accessible application programs that implement the range of functionality available in the client

In addition, the work stations that operate an ECS client subsystem contain infrastructure support software, which is part of CSMS, and platform operating support, such as the vendor operating system and its supporting software libraries.

3.1.6 Interoperability Subsystem

The Interoperability subsystem provides advertisements about both ECS and non-ECS services, providers, and data.

- The subsystem accepts advertisements, subscriptions, and search requests from the Client subsystem.
- The subsystem accepts search requests from the Ingest, Planning, and Processing subsystems.
- The subsystem also accepts advertisements and subscriptions from the Data Server and Data Management subsystems.
- The subsystem also receives advertisement and subscriptions from non-ECS service providers such as International Partners (IPs), SCFs, and ADCs.
- The Interoperability subsystem receives life-cycle commands and mode requests from the MSS and logs events with the MSS.

3.1.7 Data Management Subsystem

The Data Management subsystem provides services that search for, locate, and access data on behalf of a user or another program. Data Management services decouple users and programs from the methods a site uses to access the data and from the manner in which the data have been named. This subsystem contains four parts, as follows:

- The data dictionary service manages the definitions of data objects; attributes; domains (valid values); and access operations available via science data servers, local information managers, and distributed information managers. The information is stored in a relational database management system. The database is replicated at each DAAC using the COTS database management system (DBMS) software to perform the replication.
- LIMs provide access to data and services at a site to the extent that the underlying data servers make their data available via this manager. The LIM accepts requests, such as a search, and produces and executes the corresponding requests that must occur at the

data servers for that site. An operator must specify to the manager what objects can be accessed at the various data servers at a site. A site can modify the manager to provide site-specific access to other data sources besides data servers.

- The DIM provides access to data and services across sites. It accepts requests, such as a search, and produces and executes the corresponding requests that must occur at the LIMs and/or data servers.
- The Version 0 Gateway (GTWAY) provides interoperability services between the ECS data server and the Version 0 client.

Drivers for the design of the Data Management subsystem are as follows:

- Decouple users and programs from the methods used by sites to access the data and the way the data are named
- Provide interoperability between the Version 0 client and the ECS data server
- Simplify data administration
- Provide site autonomy
- Provide interoperability between the ECS Workbench and the Version 0 Client servers
- Provide services for the ECS Workbench to execute distributed queries, i.e., queries that access multiple sites and possibly correlate results between sites
- Provide services for the ECS Workbench to execute queries that access multiple data servers within one site and possibly correlate results between data servers

3.2 Mission Operations

The EOC manages and controls the EOS spacecraft and instruments. The EOC is responsible for mission planning, scheduling, control, monitoring, and analysis in support of mission operations for the U.S. EOS spacecraft and instruments. The Instrument Support Terminal (IST) at the investigator site connects the PI or TL facility to the EOC in remote support of instrument monitoring and command planning. The IST Toolkit (see section 3.2.2) is a software capability that integrates with the EOC for seamless operation.

3.2.1 EOS Operations Center

There is one EOC at GSFC that is responsible for coordinating the operations of all EOS instruments, U.S. or IP, for the U.S. spacecraft in addition to the operations of the U.S. spacecraft. The EOC plans and schedules all EOS spacecraft system resources and assembles and generates conflict-free instrument schedules on the basis of preplanned management information received from the NCC, EDOS, FDF, and spacecraft analysis. The EOC merges and validates instrument software loads and command data. The EOC also provides capabilities to forward commands in real time or store them for later transmission. It validates instrument command sequences before transfer to EDOS for uplink to spacecraft. In addition, the EOC provides limit monitoring of spacecraft and instrument parameters and develops contingency plans for use during spacecraft anomalies. Figure 3-6 is a functional block diagram of the EOC.

3.2.1.1 Conceptual EOC Architecture

The EOC design is made up of nine loosely coupled functional subsystems called services (See Figure 3-6). A key requirement of the EOC architecture is to ensure that it is designed to be scaleable and extensible to support multiple spacecraft simultaneously in varying states of development, testing, and operations. The challenge in fulfilling this requirement is that the system will evolve over a period of years before the full complement of spacecraft will be designed. Thus, the primary feature of the EOC system is an evolvable architecture that facilitates reduced life cycle costs. This is accomplished through the following characteristics:

1) A single EOC that can support multiple missions concurrently. The use of logical strings provides operational flexibility. A logical string is a collection of hardware and software resources and information about how these resources are being used to provide spacecraft and instrument control and monitoring during real-time contacts, simulations, and historical replays. A unique logical string exists for each real-time scenario (i.e., contact, simulation, and historical replay). Logical strings enable an operator to monitor data from multiple sources on the same display, allowing simultaneous support to multiple spacecraft.

2) EOC functions implemented by building blocks, allowing reuse of blocks for future missions. New software will focus on mission customization requirements.

3) Development of a database-driven system to facilitate ability to add, modify, and adapt functions.

4) Hardware implementation that is platform independent.

5) Streamlined operational tasks and an automation framework to facilitate increased automation.

3.2.1.2 EOC Functional Requirements

The combination of all nine EOC services provides for normal operations as well as accommodating changes for emergencies and contingencies, including Targets of Opportunity (TOOs). TOOs are defined from a EOC point of view as late changes to schedules to accommodate science requests. The following paragraphs describe these services.

3.2.1.2.1 Planning and Scheduling Service

The Planning and Scheduling Service (P&S) generates the integrated plans and schedules for spacecraft and instrument operations. These plans and schedules are dependent upon instrument science activities, instrument support activities, and spacecraft subsystem activities. As part of the Planning and Scheduling Service, the Project Scientist at the EOC may be requested to resolve instrument scheduling conflicts while ensuring that EOS

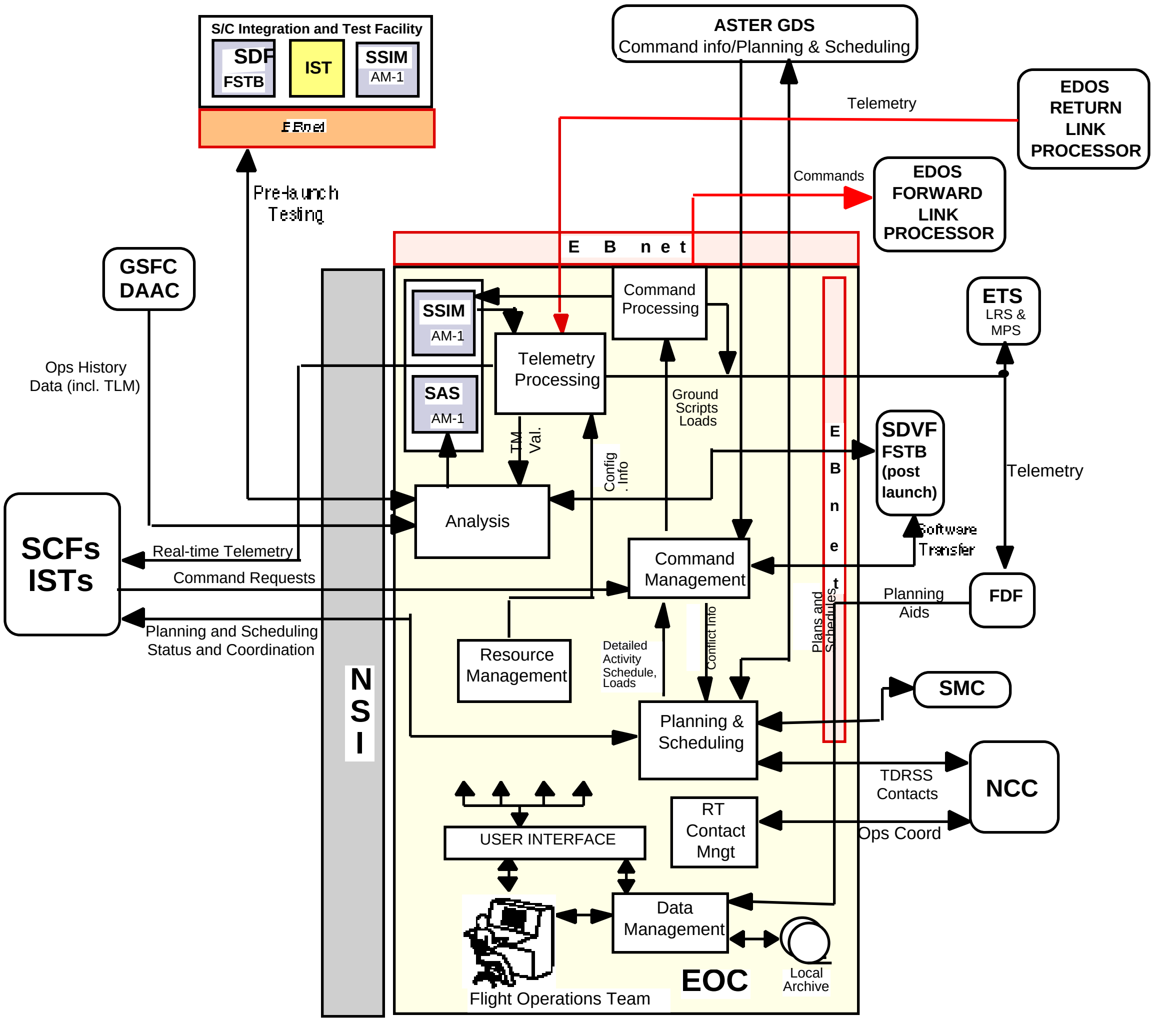

Figure 3-6. EOC Functional Diagram

mission science objectives are met. The EOC reintroduces applicable requested activities into its planning and scheduling function when the activity does not occur because of a deviation from the schedule. Plans and schedules are provided to the SDPS as user information.

The Long Term Science Plan (LTSP) is generated by the Investigator Working Group (IWG) and contains guidelines, policy, and priorities. It is generated/updated every 6 months and covers a 5-year period. The Long Term Instrument Plan (LTIP) is also generated/updated by the IWG for the same period and provides instrument-specific information. The instrument resource profile is generated/updated weekly, covering a target week, and is produced several weeks in advance. It is based on instrument science activities, instrument support activities, the previous instrument resource profile, the long-term science and instrument plans, and resource availability and guidelines from the EOC. The EOC integrates the instrument resource profiles with its spacecraft subsystem resource profile, producing the preliminary schedule. A detailed activity schedule is generated daily, covering the next several days. The detailed activity schedule can be modified for a TOO up to 24 hours before an observation. A TOO requiring no schedule changes can be accepted up to 6 hours before the observation. A TOO that requires only real-time commands can be accepted 1 hour before the next station contact. Figure 3-7 summarizes the planning and scheduling activity.

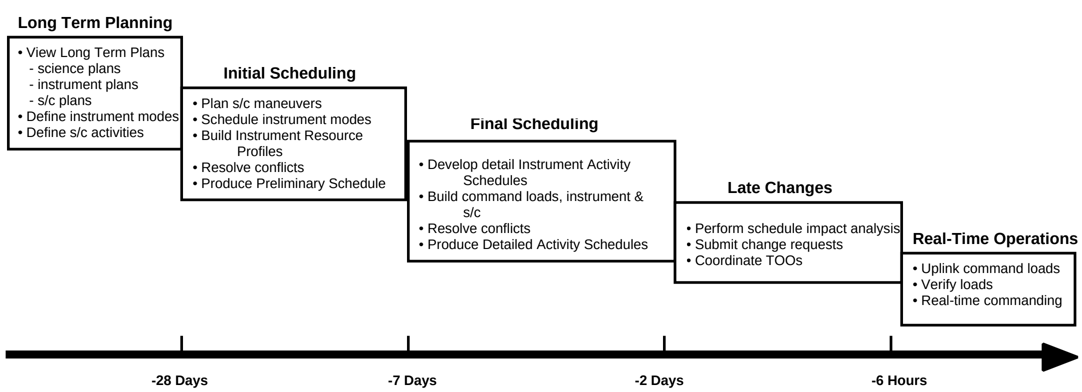

Figure 3-7. Planning and Scheduling

The EOC receives from the FDF predicted orbit data, including predicted ground track information for scheduling. The EOC assists the FDF in developing plans for spacecraft maneuvers that the EOC then implements. The EOC manages spacecraft resources that are not managed onboard, including scheduling the spacecraft recorders and communications subsystems.

3.2.1.2.2 Command Management Service

The Command Management Service provides management of preplanned uplink data for the EOS spacecraft and EOS instruments primarily on the basis of the detailed activity schedule. The Command Management Service accepts SCC-stored instrument commands, SCC-stored instrument tables, and instrument microprocessor memory loads and validates them for appropriateness, checking for authorized sources and for violation of selected constraints. It integrates the SCC-stored spacecraft and instrument commands in preparation for uplink, manages spacecraft computer stored command memory, packages commands for onboard storage, and produces a memory map for the spacecraft stored command processor. The service also provides high-level validation for preplanned command groups, which are stored on the ground in preparation for real-time execution.

3.2.1.2.3 Commanding Service

The Commanding Service in the EOC will provide the capability to transmit uplink data to the EOS spacecraft and instruments via EDOS. Uplink data are made available to the EOC Commanding Service by the EOC operators or the EOC Command Management Service.

The EOC operators will require that real-time spacecraft and instrument commands be constructed and uplinked in real time during contacts with the spacecraft. The EOC Commanding Service performs the processing necessary for this function. In this category, commands are either entered directly by the operator or generated from either a real-time or preplanned command group. (A command group is a logical set of commands. A preplanned command group is one that has been preprocessed by the Command Management Service and stored on the ground for later uplink, whereas a real-time command group has not undergone any preprocessing.)

3.2.1.2.4 Telemetry Processing Service

The Telemetry Processing Service provides the capability to receive and process both real-time and spacecraft recorder housekeeping data from the EOS spacecraft and instruments. This housekeeping data will be downlinked from the spacecraft and instrument in Consultative Committee for Space Data Systems (CCSDS) packets. EDOS will transfer the packets to the EOC.

When receiving real-time housekeeping telemetry, the Telemetry Processing Service decommutates the contents of the packets, performing the necessary conversions and calibration and determining values for other derived parameters. Various forms of limit checking are performed on the housekeeping parameters, including boundary limit checking on nondiscrete parameters, delta limit checking (examining the difference between successive parameter sample), and rail limit checking (checking for saturated parameter values). For each parameter being checked for boundary limits, the Telemetry Processing Service uses one of several limit sets, in which each limit set consists of definition for one or more upper and lower boundaries for the parameter. (These are commonly referred to as red/yellow, high/low limit sets.) All parameters, along with associated limits, quality, and event information, are made available to the operator of the User Interface Service. The

Telemetry Processing Service also extracts a subset of the real-time telemetry stream for transfer to the FDF and the ISTs.

3.2.1.2.5 Spacecraft Analysis Service

The Spacecraft Analysis Service provides the EOC operators the capabilities needed to perform spacecraft systems management, performance analysis, trend analysis, CM, and resource management. These functions are provided on a noninterference basis with real-time telemetry processing functions. A subset of these functions is provided in real time. The spacecraft analysis service also supports fault detection and isolation.

The EOS evaluates the performance of the spacecraft core systems and the status of instruments. Performance data are processed from spacecraft recorder housekeeping data, history files, and real-time housekeeping data. The EOC reports on the quality of the data used for the analysis, reports failures detected, and identifies marginal system operation. The EOC enables operators to analyze the performance of the power, command and data handling, thermal, communications, and guidance navigation and control subsystems.

3.2.1.2.6 Data Management Service

The EOC Data Management Service generates and maintains a Project Data Base (PDB) and a history log. The PDB contains descriptions of all spacecraft housekeeping data formats, housekeeping parameter descriptions, command formats, display formats, and operator directives needed to evaluate the health and safety of the spacecraft and instruments. The history log is used for maintaining the records of all spacecraft and instrument operations activities. It includes commands sent to the spacecraft and instruments, telemetry data received, NCC messages sent and received, operator directives, element manager directives, a SCC ground reference image, and event and alarm messages.

3.2.1.2.7 Resource Management Service

The EOC Resource Management Service has capabilities to schedule EOC activities, manage the configuration of the EOC hardware and software, control and monitor the configuration of its components, monitor performance, manage operator and remote system access information, generate reports, and provide operations testing. It coordinates operations with EDOS and the SMC.

3.2.1.2.8 User Interface Service

The User Interface Service in the EOC provides authorized EOC personnel with access to every function, including planning and scheduling, control and monitoring, and analysis and management of the spacecraft, instruments, and the EOC itself. This User Interface Service consists of two main capabilities: a set of mechanisms through which the operator can specify actions to be taken by the system and provide responses and input and a display function through which the user can monitor the spacecraft, instruments, the EOC components, and the results of user requests.

3.2.1.2.9 Real-time Contact Manager

The Real-time Contact Manager is responsible for receiving periodic status information from EDOS and the Network Control Center (NCC) during real-time contacts with EOS spacecraft. This status information includes monitor blocks and operation messages. In addition, the Real-time Contact Manager can send ground configuration messages to the NCC during a real-time contact.

3.2.1.3 EOC Interfaces

The primary EOC interfaces are defined as follows:

DAAC: The EOC provides the GSFC DAAC with spacecraft status information and historical data about EOS mission operation for archiving. The EOC receives from the GSFC DAAC storage status that indicates the success or failure of storage of the data the EOC sends to the DAAC.

EDOS: The EOC provides spacecraft and instrument uplink data to EDOS. EDOS provides CCSDS packets containing real-time or spacecraft recorder and instrument housekeeping data, spacecraft and instrument command status data, and spacecraft processor memory dump data to the EOC. The EOC and EDOS exchange accounting, fault coordination, data operations status, and planning information. The EOC interfaces with EDOS to request changes in data delivery services and to make inquiries into data delivery status. EDOS provides the EOC with the data delivery service status.

FDF: The EOC receives from the FDF predicted orbit data, including predicted ground track for scheduling. The EOC receives from the FDF contact scheduling data, including antenna views and predicted site acquisition tables (PSATs). The FDF develops plans for corrective firings for spacecraft maneuvers in conjunction with the EOC. The EOC receives, schedules, and implement these plans. The EOC provides attitude sensor data to the FDF for determining spacecraft attitude.

SDPS: The EOC sends copies of acquisition plans and schedules to the SDPS during its planning and scheduling activities to provide the user with information. The EOC provides the SDPS with spacecraft information used in DAR generation, including orbit data.

IP instrument control center (ICC): The EOC exchanges planning and scheduling information with the IP ICC, sends mission status to the IP ICC, and receives instrument commands and status from the IP ICC.

IST: In its role as mission coordinator, the EOC exchanges instrument planning and scheduling information with the IST, complying with the concept of global access to planning and scheduling information. In response to the scheduling process, the IST generates instrument uplink data consisting of SCC-stored commands, SCC-stored tables, and instrument microprocessor loads that implement the scheduled observations. The EOC accepts instrument uplink data from the IST, validates them at a high level, and integrates them. The instrument team is responsible for the contents of its instrument microprocessor loads. In its role as overseer of mission operations, the EOC receives instrument status information from the IST to perform high-level monitoring.

NCC: The EOC receives from the NCC forecast and active schedules of ground station and TDRSS contacts. The EOC transmits schedule requests for ground station start times and duration to the NCC. The EOC and the NCC exchange messages that include status and resource reconfiguration information.

SMC: Via the SMC, the EOC receives EOS management and operation directives, including science policy and guidelines from the IWG plan, contained in the LTSP and LTIP. The EOC returns EOC management and operations status.

Spacecraft Simulator and Software Development and Validation Facility (SDVF): The EOC receives flight software updates for uplink to the spacecraft from the SDVF. For training and simulation, the EOC sends spacecraft and instrument commands and simulator directives to the spacecraft simulator. The spacecraft simulators send telemetry data and simulator responses to the EOC. The spacecraft simulators fulfill the purpose of flight operator training, validation of operational procedures, and anomaly resolution.

3.2.2 Instrument Support Toolkit

An Instrument Support Toolkit (IST) is a collection of software executable programs that support remote participation by ECS instrument teams in the scheduling, monitoring and analysis of their instruments. This toolkit running at a workstation constitutes the Instrument Support Terminal. Using the IST, the Instrument Operations Team can schedule, monitor real-time telemetry, monitor replay telemetry (including spacecraft recorded telemetry), perform analysis, build command procedures, submit command requests, monitor commanding, review ground scripts, submit table loads and microprocessor memory loads, browse and submit updates to the instrument databases, receive event messages, access documentation, send and receive electronic mail to and from other ISTs and the EOC, build customized telemetry displays, and receive context-sensitive help.

The IST is a window into the EOC, providing much of the functionality available to the Flight Operations Team, only distributed to the PI/TL facility. The IST can be thought of as just another user station in the EOC with the following limitations:

- No real-time command capability
- Command requests may only be made for the particular PI/TL instrument
- Planning and Scheduling update requests may only be made for the particular PI/TL instrument

3.2.2.1 Conceptual IST Architecture

The IST provides remote access to EOC functions for the purpose of specific instrument scheduling, command requests, monitoring, and analysis. Its design

- Allows for multiple user access per instrument site
- Does not limit any IST capabilities to one physical IST

- Can be implemented on a variety of platforms
- Protects the EOC from unauthorized access

Since the IST is a collection of software that runs on PI/TL provided hardware, there are no restrictions on the number of software packages for any one instrument team. To manage EOC resources, there is a restriction on the number of ISTs that simultaneously can be logged in to the EOC. The number of simultaneous IST users is 15.

There are 10 dedicated simultaneous IST connections at the following locations:

- CERES 4 at Langley
- MODIS 2 at GSFC
- MOPITT 1 at U of Toronto, 1 at NCAR in Boulder
- MISR 2 at JPL

In addition, 7 nondedicated IST connections are at the following locations:

- CERES 4 at Langley
- MODIS 1 at GSFC
- MISR 1 at JPL
- Valley Forge (AM-1 spacecraft developer)

Another potential IST site is Japan (ASTER).

3.2.2.2 IST Functional Requirements

The IST subset of EOC functions includes the following:

Planning and Scheduling: During all phases of scheduling, P&S provides authorized users with a set of tools for schedule development and global schedule visualization. The P&S Timeline tool provides the IOT at an IST with global visibility into planned operations of all EOS instruments and the spacecraft. The IOT may define activities for their instrument and submit scheduling requests using these activities.

Command Management: EOC tools that may be used to generate and maintain loads are available at the IST. These tools may be used to create or edit real-time-server (RTS) load contents files; to create or edit table load contents files; to transfer load contents files from an SCF directory to an EOC directory; to generate RTS, table, or microprocessor loads in uplink format and enter them in the EOC Load Catalog; to request the scheduling of the uplink of an RTS, table, or microprocessor load, and to view the list of loads currently available in the EOC Load Catalog.

Instrument Monitor: The IST allows a user to monitor spacecraft and instrument housekeeping and instrument engineering telemetry that is being received and processed in real-time at the EOC. Additionally, the IST allows a user to monitor simulations and historical telemetry replays that are currently being processed at the EOC. (Historical telemetry includes both real-time and spacecraft recorder telemetry.) The IST allows a user to display telemetry data from one or more instruments and/or one or more spacecraft simultaneously.

Instrument Analysis: The IST provides the user the capability to perform analysis of historical telemetry that is archived at the EOC or the DAAC. (Historical telemetry includes both real-time and spacecraft recorder telemetry.) Access to historical data is through the analysis tools that allow the static viewing of history data or through the replay of history data.

3.3 Spacecraft Data Capture and Distribution

EDOS is responsible for data capture from the spacecraft, interface of uplink commands, processing and distribution of Level 0 data, and Level 0 data archival. It provides space and ground interfaces between the EOS spacecraft via the SN/TDRSS and the EGS, the EOC, and DAAC elements of EOSDIS.

EDOS services include the following capabilities: EOS spacecraft data capture, playback processing, removal of science data overlaps and duplication, data quality checking and correction, annotation of missing or fill data, disassembly of the multiplexed EOS science data packets, and generation and distribution of PDSs and Expedited Data Sets (EDSs) to DAACs. EDOS provides level zero processed data sets within 21 hours of data reception.

EDOS is distributed over four types of facilities: GSIFs that interface with TDRSS and the two polar EOSDIS ground stations to store and forward return link data, a DAF for archival of Level 0 data, a Level 0 processing facility to produce Level 0 data and process real-time data, and a sustaining engineering facility (SEF) to support current and future EDOS operations. Figure 3-8 illustrates the EDOS configuration.

3.3.1 Conceptual EDOS Architecture

EDOS provides the data capture and distribution link between EOS spacecraft and the rest of the EGS. This link is considered a major component of the EGS because of the unprecedented volume of data expected to be recorded and archived from the EOS instruments. Since the EGS is an evolutionary system, EDOS is designed to address the evolution in spacecraft design, instrument design, ground system hardware/software, and standards. The EDOS design incorporates advances in information technology as well as communication, networking, data processing, and archival technologies. The EDOS is also designed with sufficient flexibility to accommodate rapidly changing requirements and demands generated by users.

Some of the key concepts driving the EDOS architecture areas include the following:

- Maintain compatibility with NASA Institutional Systems
- Use data-driven systems
- Automate operations

- Provide 24-hour year-round operations
- Provide common computer human interface capabilities
- Provide a sustaining engineering environment
- Support concurrent development, testing, and operation for the life of EOS plus 3 years
- Respond to evolution of EOS requirements while supporting operations
- Simultaneously support multiple spacecraft, each in a different phase of the life cycle
- Ensure that there is no single point of failure for real-time mission data handling services

3.3.2 Ground Station Interface Facilities

The Ground Station Interface Facilities (GSIFs) consist of functions necessary to monitor and capture high rate mission data received from the TDRSS Ground Terminal(s)¾ which consist of the White Sands Ground Terminal and the Second TDRSSGround Terminal¾ or from the EOSDIS ground stations, and to transfer captured data to the Level Zero Processing Facility (LZPF) at a reduced rate. GSIF capabilities are provided by the following functions:

a. The Short Term Data Capture function provides high-rate return link interface capabilities between the GSIF and the ground terminals for temporary capture of return link data from the spacecraft for subsequent transfer to the LZPF at reduced data rates. GSIF is also responsible for temporary storage of spacecraft data for 24 hours.

b. The Operations Management function provides the capabilities for GSIF control and monitoring and management interfaces.

c. The Return Link Monitoring function provides high-rate return link interface capabilities between the GSIF and the ground terminals and generates real-time return link physical channel quality and accounting data and transfers these data to the LZPF.

d. The System Support function provides support capabilities for GSIF hardware maintenance and capabilities to test the GSIF functions and interfaces, simulate external interfaces, execute tests, record data, and support external element interface testing.

The GSIF for AM-1 is located at the White Sands Facility. To back up White Sands, AM-1 backup ground stations located at Spitzbergen, Norway, and Alaska capture downlink data and forward the data via tape to the LZPF. Follow-on EOS missions (e.g., PM-1 and CHEM) will be primarily supported from GSIFs located with their Ground Terminal facilities at Spitzbergen, Norway, and Alaska.

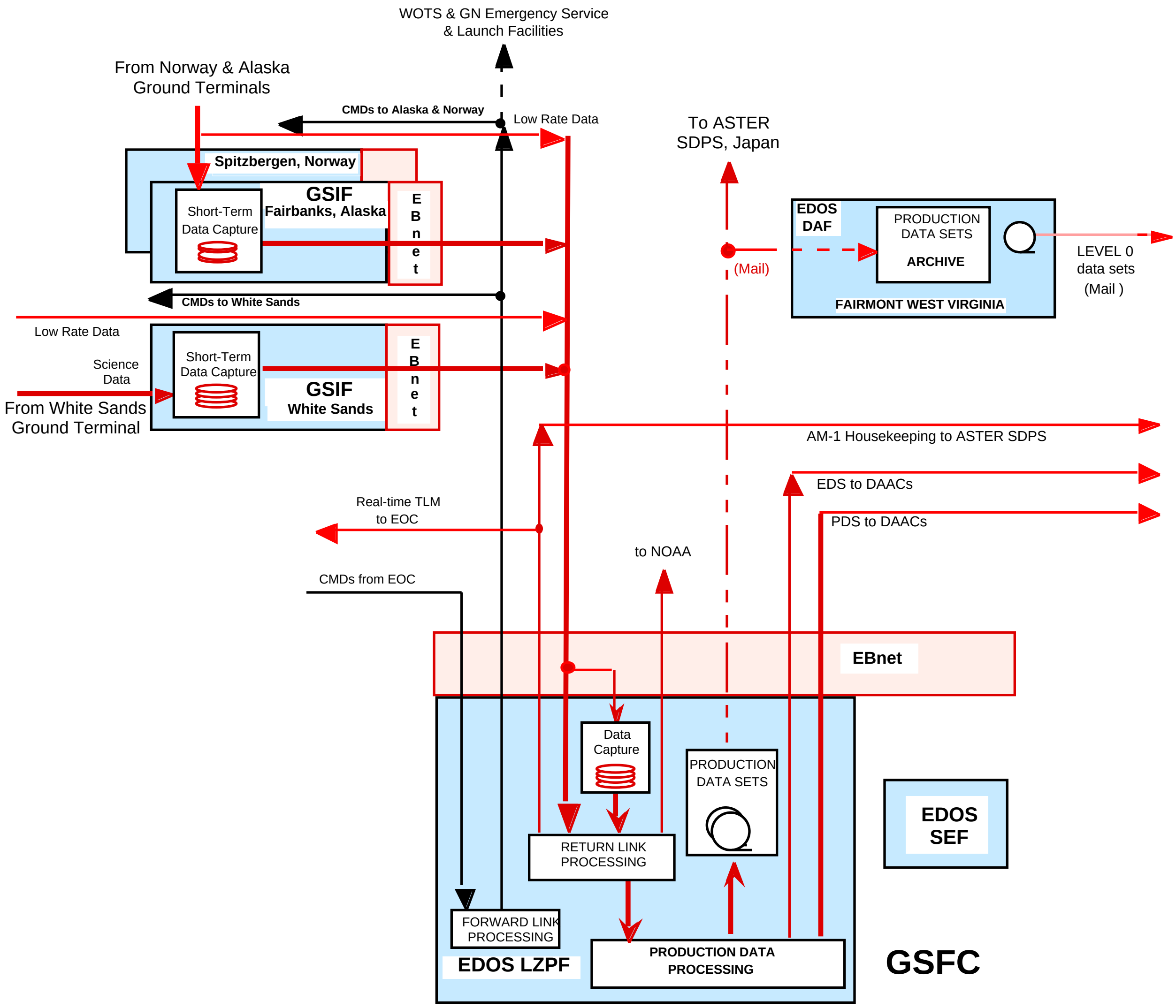

Figure 3-8. EDOS Configuration

3.3.3 Level Zero Processing Facility

The LZPF consists of functions necessary to process and transfer mission data between ground terminals and EGS elements. Processing performed by the LZPF consists of data capture, real-time forward link and return link processing, rate buffering, production data handling, and distribution of return link data. Production data handling consists of creation and distribution of PDSs and EDSs. In addition, the LZPF provides the EDOS system management and IV&V and maintenance support capabilities. LZPF capabilities are provided by the following functions:

a. The Data Capture function provides for capture and short-term storage of all received return link data.

b. The Return Link Processing function provides return link interface capabilities between the LZPF and the ground stations. It also

- Generates return link physical channel quality and accounting data.
- Provides processing of return link data in support of the CCSDS virtual channel data unit (VCDU) and Path Services.
- Appends quality and accounting data to the return link data.
- Provides reversal of playback data, rate buffering, and transfer of return link data to its designated destination.

c. The Forward Link Processing function provides the forward link interface capabilities between the EOC and the ground terminals, generates quality and accounting data, and transfers forward link data to the EOS spacecraft via the TDRSS Ground Terminals, EOSDIS Ground Terminals, DSN, GN, and WOTS.

d. The Production Data Handling function provides production data processing and expedited data processing. It also

- Produces and distribute PDSs and EDSs with full quality and accounting data appended. Level zero data are distributed electronically or via removable physical media as PDSs within 21 hours of receipt. EDSs are distributed electronically.
- Produces PDS archive data for the EDOS Data Archive Facility (DAF) backup archive service.

e. The Operations Management function provides the capabilities of EDOS control and monitoring, planning and scheduling, and management interfaces. It also provides capabilities to coordinate the operations of EDOS services, monitor end-to-end performance, coordinate EDOS/EBnet fault management, verify operational readiness, and transfer EDOS service reports to EGS elements.

f. The System Support function provides support capabilities for EDOS hardware maintenance and capabilities to test the EDOS functions and interfaces, simulate external interfaces, generate test data, execute tests, record data, analyze test results, and support EGS element interface testing.

The LZPF is located at GSFC, Greenbelt, Maryland. It interfaces EDSs and PDSs electronically with the DAACs and provides PDSs on removable physical media via mail to the DAF and the ASTER SDPS in Japan. In addition, it interfaces real-time telemetry data between the EOC and the GSIFs and command data between the EOC and the ground stations.

3.3.4 Data Archive Facility

The DAF consists of functions necessary to accept and archive PDSs from the LZPF on removable physical media. The DAF distributes archived PDSs via removable physical media upon request. The DAF provides backup archive of all PDSs processed by EDOS for the life of EOS plus 3 years. The DAF is located in Fairmont, West Virginia.

3.3.5 Sustaining Engineering Facility

The SEF is located at GSFC, Greenbelt, Maryland. The SEF provides EDOS with engineering support, operations management, system support, and communications interface.

a. Characteristics of engineering support services are as follows:

- Provides a hardware and software development/sustaining engineering environment
- Provides the capability to upgrade EDOS as system requirements change
- Maintains a library of historical data to track and manage EDOS project documentation, systems descriptions, user guides, utilities, test plans, and other related documents
- Provides for the development of training procedures, manuals, plans, and other functions required to train EDOS personnel

b. Characteristics of operations management services are as follows:

- Performs trend analysis on operational data from the GSIF and LZPF
- Monitors SEF systems
- Coordinates EDOS/EBnet operations and services, support fault isolation, and recovery processing
- Provides integration, test and verification support, and system maintenance support

3.4 Data Communications

Data communication for the EOSDIS is wide ranging and varied as benefits a complex of many modes, sites, and facilities. While the topography of the communication networks is concentrated in the lower 48 states of the continental United States, numerous international partners and users must also be served via data gateways and through existing external communication services.

In general, the data communications for EOSDIS can be characterized as internal and external, whereas the internal capabilities are mostly provided by the EBnet or by other unique Nascom capabilities, interconnecting dedicated capabilities within the EOSDIS; the external capabilities are provided by the NASA Science Internet (NSI) and the Internet, servicing remote investigators and user facilities. Table 3-2 shows the functions and providers for these two aspects of EOSDIS data communications. Data communications services are largely transparent and unobtrusive to the user.

Implementation of data communications for EOSDIS is primarily an extension or improvement of existing capabilities, using COTS products and commercially available components. Telecommunications circuits are acquired from common carriers using broad government contracts (e.g. FTS 2000). Bandwidth and circuits provide at least a 50 percent margin over the basic traffic estimates for the combination of each individual data flow or product specification in EOSDIS.

Table 3-2. Two EOSDIS Networks

NETWORK	**EOSDIS Backbone Network (EBnet)**	**NASA Science Internet (NSI)**
FUNCTIONS	**Internal data flows:** • Real-time command and Control • Level 0 data • Production flow	**External data flows:** • ISTs • SCFs • QA • General users
PROVIDER	Nascom GSFC Code 540	NSIPO NASA ARC

3.4.1 EOSDIS Backbone Network

The EBnet Project provides a unique ground-to-ground data transport system for operational EOS communications; EBnet is being built to address EOS-specific requirements, although it may support other activities as well. The system provided by EBnet transports forward link commands, return link telemetry, payload science data, and operational data flowing among the DAACs, ground stations, EDOS, the EOC, the FDF, test and spacecraft support facilities, and selected project or instrument remote sites. Some of the requirements and goal for EBnet include the following:

- Implement an automated system maximizing use of COTS equipment
- Maintain compatibility with existing versions of NASA institutional systems, the Version 0 networks, and the Nascom Operational LAN (NOLAN) systems as needed to meet EOSDIS requirements
- Transport traffic in a data-driven mode between specified locations as collected and maintained in an EBnet traffic database and provide a margin of capability beyond the specified aggregate flows

- Minimize life-cycle costs for implementation, operation, and maintenance of the network, operating with a minimum of human intervention

- Accommodate concurrent operations, simulators, and testing

- Allow for growth, adaptability to changing requirements, infusion of new technology, and upgrading of interfaces throughout its life cycle

The Network Management Control Center (NMCC) is a part of EBnet that monitors, manages, and controls the operation of the network and that interfaces with the ECS SMC.

The NMCC provides network monitoring and control capabilities to manage and display network topology and resource allocation; manages network operations, administration, planning and security functions; performs fault management functions, including fault detection, isolation, and resolution; and collects and reports accounting and network utilization information.

3.4.2 Other Nascom Support

Certain circuit and related capabilities are provided to EOSDIS independent of the EBnet, from prior arrangements or because of the special nature or attributes of the service. This includes controlling and scheduling resources (the NCC), TRMM Project Science data acquisition by the SDPF, and higher level data products flows by the TRMM Science Data and Information System (TSDIS).

3.4.3 NSI/Internet

The NSI is an open computer communications network that serves the needs of NASA's diverse science and research community worldwide. NSI's mission is to support NASA's scientific goals and objectives by providing reliable global network communications for scientific research. It accomplishes its mission by identifying and managing all existing and future NASA science network requirements, engineering high-quality solutions in a evolving environment, developing tools to enhance the usefulness of the network, and providing information on how to find and use networking resources.

NSI was established in 1988. In 1989, both the DECnet-based Space Physics Analysis Networks and the Transmission Control Protocol/Internet Protocol (TCP/IP) based NASA Science Network were brought together as a single project called NSI. Today, NSI is a high-speed, multiprotocol, international network that supports both DECnet and TCP/IP protocols. NSI currently serves nearly 10,000 NASA researchers and collaborators worldwide, with high-performance links and gateways connecting to several thousand research, educational, and public commercial networks via the Internet and national research networks in Europe, Asia, and other continents.

In EOSDIS, the NSI will connect the DAACs, SCFs (ISTs), and the EOC within ECS for planning and scheduling; will support flight operations; and will perform monitoring and coordination activities. It will connect the ISTs, SCFs, and quality control (QC) SCFs within EOSDIS, as well as general users, ADCs, ODCs, and other external partners.

3.4.4 Other Data Communications Capabilities

The WANs provided by EBnet and NSI typically connect to LANs at each site that are provided by the host there. In a few instances, EBnet provides the data flow at a local site in place of the LAN (e.g. at EDC for Landsat-7 data), but this circumstance is an exception.

Mail is also used as a data communications tool within the EOSDIS for archive products on hard media and for productions data sets in some cases.

3.5 System Monitoring and Coordination Center

Formerly called the System Management Center, the SMC is one of the elements of the ECS CSMS. This element performs systemwide, site, and element resource and operations monitoring and provides these services to the other ECS elements. The SMC interacts with all the other elements of the ECS as well as interfaces with external systems, ADCs, and ODCs.

The main mission of the SMC is to provide a center where a systemwide view of the ECS operations can be maintained for operations personnel. This center, located at GSFC, can provide systemwide coordination of activities at individual sites and element locations by providing high-level resource configuration directions and schedule adjustments. The center also provides a source for systemwide administrative, security, and accounting management. Operations personnel guide these services.

To accomplish effective coordination between the SMC and the other ECS elements, the SMC provides each element with LSM services. The LSM is the local management and operations component running on each element's architecture. The LSM provides means by which local management and operations personnel control and monitor their ground resources.

Site managers monitor each of their element's ground operations activities at their particular sites.

SMC monitors the ground operations events of each site and element.

Communication is established among the SMC, sites, and elements for management operations information, including directives, status, and user information.

Figure 3-9 shows the context of the SMC in EOSDIS. The interaction between the SMC and the ECS elements and the other interfaces varies from element to element and from place to place. Coordination of activities extends into CM, security, engineering maintenance, logistics, and upgrades for the managed ECS elements.

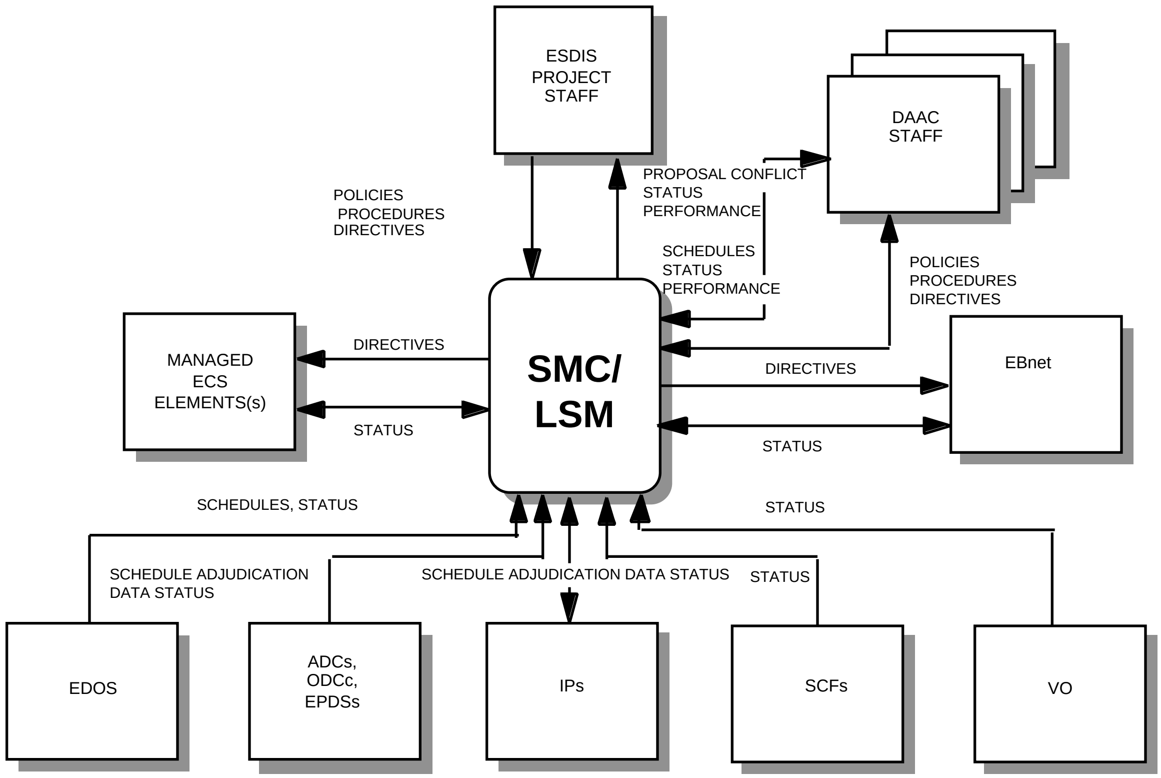

Figure 3-9. SMC in Context With EOSDIS

3.5.1 SMC Implementation

Implementation of the SMC is accomplished via a systems management subsystem (the MSS). Figure 3-10 shows the MSS high-level context. The MSS is composed of a combination of COTS and custom management applications to provide a highly automated means for monitoring and managing the various ECS resources. At each ECS installation, maintenance and operations (M&O) staff autonomously provide local management services associated with its ECS resources, and hence, they are provided a local management view. At the GSFC SMC, M&O staff provide enterprise monitoring and coordination services associated with all ECS installations, and they are provided a systemwide management view. The MSS applications provide extensive configurability to enable these views to be shared or controlled as necessary on the basis of ECS management policy. In addition to providing these views to M&O staff for monitoring and control purposes, the management services make use of legacy communications subsystem (CSS) services, such as electronic mail and bulletin boards for coordination. The services provided by CSMS at the SMC, located at GSFC, are collectively referred to as Enterprise Monitoring and Coordination (EMC). In the same context, services provided by CSMS at DAACs and the EOC (sites) are collectively referred to as LSMs.

The MSS provides EMC (network and system level) for all ECS resources: commercial hardware (including computers, peripherals, and network routing devices), commercial software, and custom applications. EMC reduces overall development and equipment costs, improves operational robustness, and promotes compatibility with evolving industry and government standards. Consistent with the current trends in industry, the MSS thus manages both ECS's network resources as per EBnet requirements and ECS's host/application resources as per SMC requirements. In addition, the MSS also supports many requirements allocated to SDPS and FOS for management data collection and analysis/distribution.

3.5.2 MSS Service Allocation

The MSS allocates services to both the systemwide and local levels. With few exceptions, the management services are fully autonomous, and no single point of failure exists that would preclude user access. In principle, every service is distributed unless an overriding reason demands it to be centralized. MSS has two key specializations: EMC and LSM. The distribution of these services, shown in Table 3-3, provides maximum flexibility and policy neutrality in the design and implementation of MSS services.

Client-server system management application services for distributed enterprises, such as ECS, are not commercially available today. A framework has been chosen for integration of multivendor network and system management products to support migration to a fully integrated management solution as such products become commercially available.

The MSS is largely in the application domain, above the Open Systems Interconnection Reference Model application layer services. The management applications are supported by, and are functionally dependent on, other MSS and CSS services. The Management Agent Services are used to monitor and control managed objects (such as network, hardware, and software) within each management domain and provide the primary means of communicating status and control information between managed objects and management applications.

3.5.3 MSS Implementation

The MSS is implemented mainly through the use of COTS, with some "wrapper" and custom code to support ECS-unique requirements and a layer of abstraction from COTS to minimize effect of migration of new technology or enhancements. The selection of each COTS package takes into consideration factors such as ECS requirements, commonality of the man-machine interface, integration with the chosen framework, adherence to standards, vendor track record, and flexibility of operation.

The MSS implementation uses the common framework for integration of the suite of common management functions, providing elements of fault management, CM, accountability management, performance management, security management, and mode management. This framework and integrated applications use the de facto industry standard Simple Network Management Protocol (SNMP) as the primary means of monitoring and controlling ECS management objects.

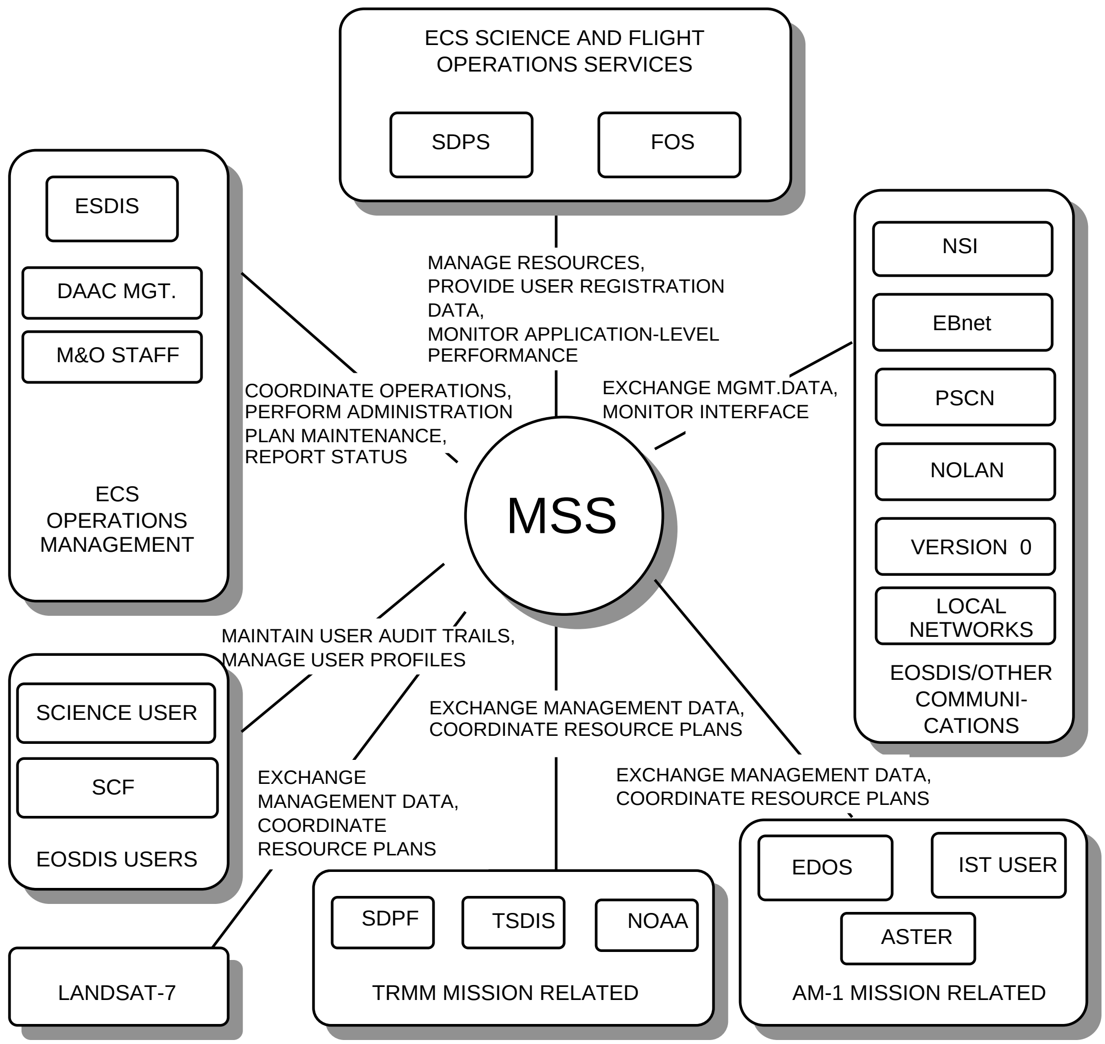

Figure 3-10. MSS High-Level Context

Table 3-3. Management Service Distribution (1 of 3)

Management Service	EMC	LSM	Comments
Policies and Procedures	Provide policy decisions, coordinate policy, monitor policy compliance	Coordinate policy and site-level policy decisions, policy compliance monitoring and reporting	Policy management and decisions are made by people using these tools
Fault Management	Receive summary reports from sites; monitor systemwide resources (WANs); perform trend analysis	Monitor, detect, isolate, diagnose, and recover from faults within domain	Largely COTS capabilities (HPOV); EMC maintains systemwide view from site updates and monitoring
Performance	Provide trend analysis and systemwide view from site updates	Collect server, hardware, and network performance data, analyze performance data; tune and report to SDPS/FOS/EMC	Site performance is cooperative effort between LSM and SDPS/FOS; trends are through rollup of site reports
Trouble Ticketing (TT)	Provide summary reports; view selected site problems, support resolution	Document problem reports, track actions and closure; provide user and resource summaries	Remedy selected as TT package
Physical Configuration Management	Maintain same information as LSMs	Maintain physical location and configuration information	Commercial package to locate and record resources; detects changes to approved configuration
Security	Provide policy flowdown, systemwide monitoring and analysis	Provide DCE cell management	Authentication, authorization, intrusion detection, distributed computing environment cell management; largely public domain and COTS, HAL for cell management policy flowdown; administration is through offline analysis tools
Inventory	Create and manage systemwide inventory	Maintain and manage site inventory data	Automated

Table 3-3. Management Service Distribution (2 of 3)

Management Service	**EMC**	**LSM**	**Comments**
Logistics	Provide systemwide monitoring of spares and consumables	Provide site-level monitoring of spares and consumables including replenishment	Automated
Maintenance	Provide systemwide maintenance analysis	Establish and maintain PM schedules; monitor and coordinate offsite maintenance	Automated
Configuration Management	(Software Change manager)	Provide software CM of ECS baseline	
Baseline Manager	Provide consolidated baseline for systemwide configuration and dependencies	Maintain site baseline for operational system configuration	
Change Request Manager	Maintain system-wide status of change requests	Maintain record of configuration change requests; track status	
Training	Coordinate training schedules, curricula, user feedback, and develop materials	Provide input on training schedules, curricula, local course development, and evaluation	Automated
Planning	Provide systemwide schedule policy, priorities, performance assessment, systemwide ground event coordination	Schedule own resources based on systemwide priorities and policies; plan ground events; and interface with FOS and PDPS	
Reports	Provide systemwide reporting based on “rollup” of site-level data	Provide site-level reporting on performance, security, fault, and configuration information	

Table 3-3. Management Service Distribution (3 of 3)

Management Service	EMC	LSM	Comments
Billing and Accounting	Receive user resource utilization and data order information; provide capability to price resources and products; maintain standard pricing tables; generate statements of account and bill invoices; track accounting data	Collect and provide user resource utilization and data order information; query account data	Tracking and billing for resources used by users
Mode Management	Coordinate and monitor mode activities across sites	Coordinate and monitor mode activities within a given site	Maintain systemwide view and control of different modes of activity

The MSS design depends heavily on COTS products, each of which is configured to support ECS-unique requirements. Custom code development for services is roughly uniform across each service and is estimated at 50 to 60 KSLOC. The framework must be configured to support the ECS-specific design and implementation. Part of this configuration can automatically detect network devices that support the industry standard SNMP. Identification of other ECS-managed objects is provided by custom development in the Management Agent to add these elements to the database. This information, along with mode management information, is used to build operations maps that depict the logical layout of network devices and other ECS-managed objects. Part of the configuration then entails the definition of operation "views" that support different operation modes within ECS. A second significant part of the configuration is developing scripts that define action routines for each event that is received for each managed object. The other services shown in Table 3-3 require varying amounts of configuration and customization. Integration effort into the framework is minimized through selection of COTS that have already been integrated by the vendor whenever possible.

The hardware for MSS contains an Enterprise Monitoring server, LSM servers, management workstations, and printers. The selection of these configurations results from requirements and trades analysis and performance, RMA, security, and evolvability considerations. Hardware configurations and sizing are made DAAC specific. Major design drivers include the number of managed objects, size and frequency of data to be collected about the managed objects, data distribution, data retention and archiving design, and COTS choices.

3.6 EOS Test System

The EOS Test System (ETS) consists of three data flow simulators located at GSFC Building 32 that test key EOSDIS data interfaces at the EOC, DAACs, EDOS, and Ground Terminals. These three simulators are as follows:

- The Multimode Portable Simulator (MPS)¾low fidelity spacecraft simulator to support testing of forward-link and non-science return-link processing
- The High-Rate System (HRS)¾EOSDIS return-link science data processing and interface test tool
- The Low-Rate System (LRS)¾functional EDOS interface between the EOC and either the Spacecraft Integration and Test Facility (SCITF) or Spacecraft Simulator (SSIM).

NASA GSFC Code 515 is developing the ETS.

3.6.1 Conceptual ETS Architecture

The ETS components are shown in context with the EGS in Figure 3-11. The architecture of the ETS is driven by the large difference in data rates to be simulated, the need to support five configurations for testing and simulations, and the utilization of in-house technology. Figure 3-12 illustrates the ETS architecture.

3.6.2 ETS Functional Requirements

3.6.2.1 MPS Functions

The MPS simulates the S-band telemetry and command format interfaces with the EDOS and EOC, as well as the spacecraft command and telemetry interface. Its functions include the following:

- Simulate S-band telemetry formats (512 kbps playback, 16 kbps real time) and receive spacecraft commands (2 kbps or 10 kbps) to test the interface with EDOS
- Simulate low-rate telemetry formats and receive spacecraft commands in Nascom blocks to test contingency network interfaces to EDOS through EBnet
- Simulate and transmit low-rate telemetry in EDOS formats to the EOC and receive spacecraft commands from the EOC or EDOS as command data blocks
- Use the AM-1 PDB files for telemetry generation and command verification
- Provide limited telemetry responses to valid spacecraft commands
- Provide Operations Management Data simulation capabilities for subset of EDOS and EOC OMD

3.6.2.2 HRS Functions

The HRS simulates the high-rate science data stream to test the interfaces of the DAACs, EDOS, and ground terminals. Its functions include the following:

- Simulate ground terminal high-rate return link by transmitting up to two 150-Mbps serial data streams.
- Simulate EDOS output by transferring data sets to a DAAC via EBnet at sustained data rates up to 34 Mbps.
- Simulate the DAAC front end by capturing EDOS data sets via EBnet at sustained data rates up to 34 Mbps.
- Accept and playback SCITF test data on Ampex tapes.

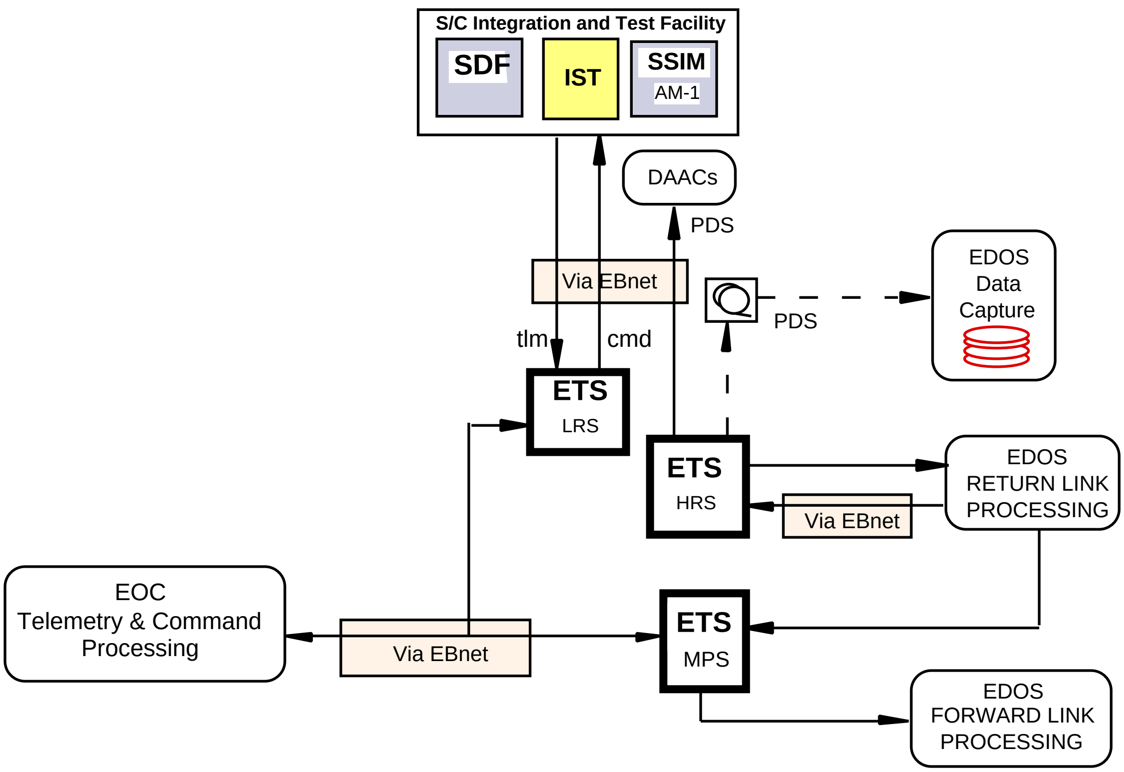

Figure 3-11. ETS Context With EGS

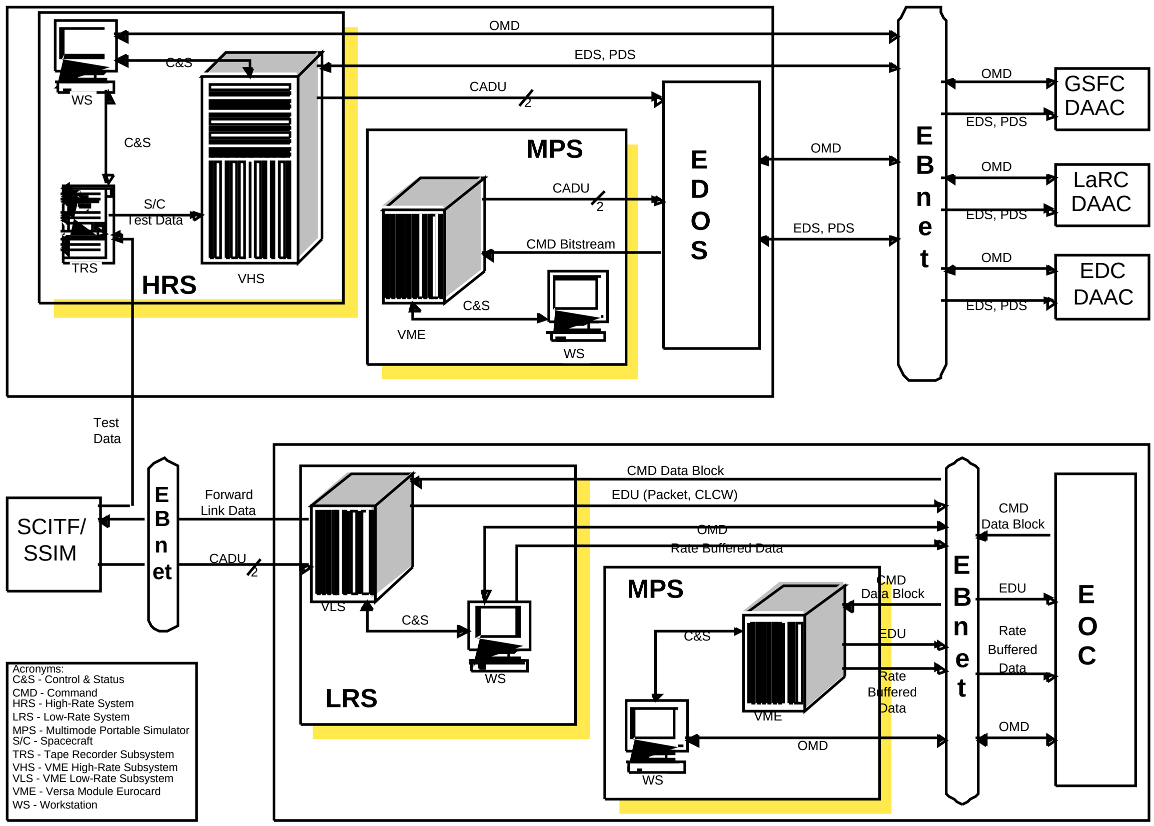

Figure 3-12. ETS Architecture

- Process SCITF test data to generate channel access data unit (CADU) files, and EDOS-compatible EDS and PDS.
- Provide a graphical unit interface based control environment that supports automated operations.

3.6.2.3 LRS Functions

The LRS simulates the EDOS forward link and return link processing functions. Its functions include the following:

- Simulate EDOS forward link processing functions by receiving Command Data Blocks, checking EDOS ground message headers, extracting forward link data, and forwarding it to SCITF/SSIM
- Transmit forward link data to SCITF/SSIM at 125 bps, 1 Kbps, 2 Kbps, or 10 Kbps
- Simulate EDOS low rate return link processing functions by receiving and processing up to two S-band serial data streams

- Perform return-link processing at data rates up to 1 Mbps
    1) Process up to 8 spacecraft IDs (SCID)
    2) Process up to 31 Virtual Channels
    3) Process up to 521 application process identifiers
    4) Process up to 521 sources
- Transmit return link data as electronic data units (EDUs) and rate buffered data files
- Provide a graphical unit interface based control environment that supports automated operations

3.6.3 ETS Interfaces

Figure 3-13 summarizes the major ETS interfaces.

3.7 EOSDIS Ground Stations

High latitude ground stations located in Alaska and Spitzbergen, Norway, will be implemented for support of EOS missions, beginning in 2000 with the PM-1 mission. These stations will interface low- and high-rate data with the EDOS in the same manner as White Sands. (Also see section 3.8.3.3.)

3.8 NASA Institutional Support Systems

The major NISS components supporting the EGS are the TDRSS Ground Segment, the NCC, JPL/DSN, GN, WOTS (for emergency support), and the FDF. Figure 3-14 shows the NISS interfaces.

3.8.1 TDRSS Ground Segment

The TDRSS Ground Segment is used for primary tracking, telemetry, and command operations for the AM-1 spacecraft. The TDRSS ground segment consists of the White Sands Ground Terminal and the Second TDRSS Ground Terminal, located at the White Sands Complex (WSC) in Las Cruces, New Mexico. The TDRSS Space Segment consists of a constellation of TDRSs in geosynchronous orbit that provide S-Band Single Access (SSA), S-Band Multiple Access (SMA), and Ku-Band Single Access (KSA) tracking and data communications services to low Earth orbiting satellites. TDRSS support is scheduled and controlled by the NCC.

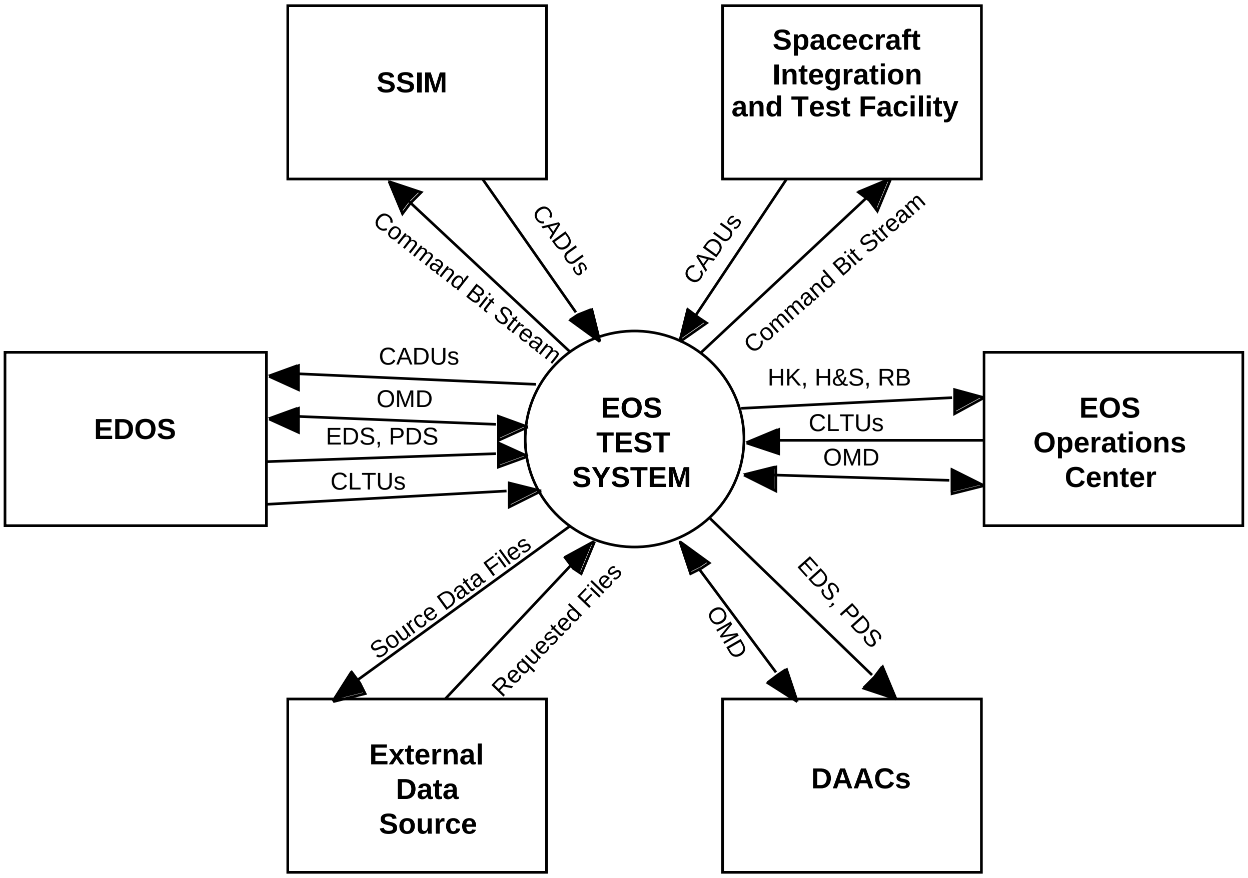

Figure 3-13. Major ETS Interfaces

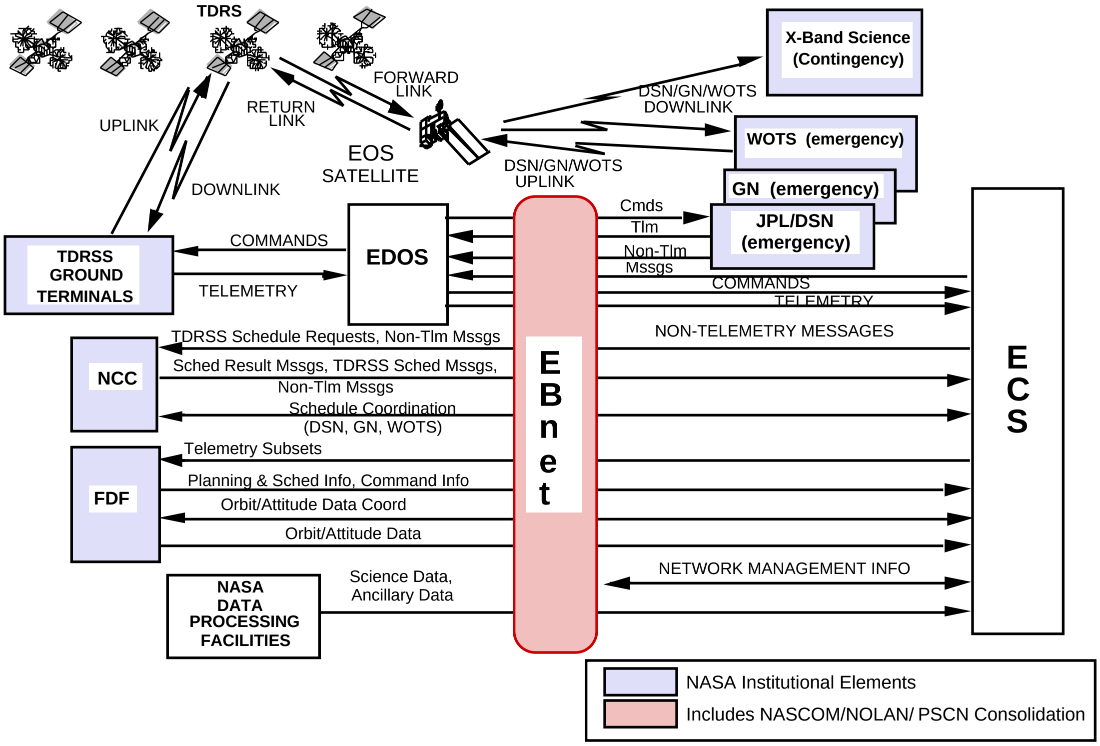

Figure 3-14. NISS Interfaces

3.8.2 Network Control Center

The NCC is the focal point for management of the SN and the GN. The NCC is responsible for scheduling of TDRSS operations and the performance of link monitoring and fault isolation. The NCC Data System consists of three major segments: The Communications and Control Segment, the Service Planning Segment, and the Intelligent Terminal Segment. In addition, a Service Accounting Segment is an offline element that provides accounting for the use of the services and resources of the SN as planned by the Service Planning Segment.

3.8.3 Ground Network, JPL Deep Space Network, Wallops Orbital Tracking Station

These facilities are utilized for emergency backup support.

3.8.3.1 Ground Network

The GN includes NASA ground station at Merritt Island, Florida, and Bermuda. The GN provides launch and landing tracking and data acquisition support and backup support to user spacecraft in lower Earth orbits. The EOS program will use GN services as a backup in case of loss of TDRSS support. These services include backup RF communication services for relaying housekeeping telemetry and low bit rate commands between the EDOS LZPF and the EOS spacecraft. GN support is coordinated through the NCC.

3.8.3.2 JPL Deep Space Network

The JPL DSN performs tracking and data processing primarily for NASA deep space missions and non-TDRSS compatible spacecraft. The DSN provides S-band emergency support for TDRSS compatible satellites, including the EOS AM-1. These services include backup RF communication services for relaying housekeeping telemetry and low bit rate commands between EDOS LZPF and the EOS spacecraft. JPL is responsible for the overall management of the DSN data systems, which consist of the JPL Network Operations Control Center, the Ground Communications Facility, and the Deep Space Communications Complexes located at Goldstone, California; Madrid, Spain; and Canberra, Australia.

3.8.3.3 Wallops Orbital Tracking Stations

The WOTS, located at Wallops Island, Virginia, provides tracking, telemetry, and command support for the non-TDRSS compatible low Earth orbiting satellites and S-band emergency support for the TDRSS satellites.

The WOTS also serves the EOS program in a backup contingency mode for relaying housekeeping telemetry and low-bit rate commands between the EOS spacecraft and the EDOS LZPF. In addition, X-band WOTS will be located in Alaska and Spitzbergen, Norway, to provide backup TDRSS science data downlink service to EOS AM-1.

3.8.4 Nascom Operational Local Area Network

The NOLAN will be used to transport science and ancillary data from NASA data processing facilities (such as the GSFC SDPF) to the DAACs for designated NASA missions like TRMM.

3.8.5 Flight Dynamics Facility

The FDF will provide orbit and attitude support for the EOS spacecraft by monitoring spacecraft attitude and navigation system performance and providing orbit and attitude products to support the EOS flight operations and science processing. The FDF also may provide orbit and attitude determination for selected future EOS spacecraft. Major functions of the FDF include the following:

- Provide orbit predictions and planning data
- Provide attitude determination support
- Provide orbit maneuver and rendezvous support
- Receive all tracking data transmitted to GSFC for real-time validation
- Maintain a database of tracking data to be used for orbit computations
- Provide mission analysis support
- Provide guidance, navigation, and control system verification

- Perform prelaunch services (e.g., trajectory analysis, sensor analysis, and operations planning)

3.9 Spacecraft Ground Support Components

3.9.1 Spacecraft Simulator

The SSIM provides ground-based simulation capabilities of the EOS AM-1 spacecraft Command and Data Handling (C&DH) subsystem. The simulation capabilities support EOS ground system test and training activities. They include support for training control center operators and testing operational procedures. The AM-1 SSIM, developed by the AM-1 spacecraft vendor, is located at GSFC. EOS missions subsequent to AM-1 will use mission simulators provided by the spacecraft contractor.

3.9.1.1 SSIM Description

The SSIM provides real-time simulation of the EOS spacecraft to support testing of flight software loads and databases, testing of operational procedures, spacecraft flight operator training, anomaly investigation training, and ground test support. The SSIM includes the following capabilities:

- Simulate and conduct spacecraft operation integration and tests, such as Spacecraft Control Computer flight software memory loads/updates and operation readiness, in support of the EOS spacecraft IV&V functions.
- Simulate end-to-end tests with ground system interfaces.
- Host spacecraft mission and simulation software.
- Simulate real-time spacecraft during various mission profiles.
- Utilize an interactive user interface, with scripted procedures.
- Function in standalone or training mode of operation.
- Provide real-time EOC interface (command and telemetry).
- Provide an administrative interface (file transfer) with FDF, contractor plant, or EOC.
- Simulate high-fidelity spacecraft dynamics, navigation, and attitude control (normal and safehold).
- Simulate low-fidelity power and thermal telemetry.
- Simulate appendage deployment.
- Simulate C&DH components (standby command and telemetry interface unit [CTIU]), solid state recorder).

- Provide canned response to commands for instruments.
- Initiate all software FDIR services.

3.9.1.2 SSIM Design Drivers

- The SSIM has the capability to receive AM-1 spacecraft and instrument commands in CCSDS command link transmission unit (CLTU) format.
- The SSIM has the capability to send (in EDUs containing CCSDS telemetry packets) simulated real time AM-1 spacecraft and instrument housekeeping telemetry packets and command link control words.
- The SSIM has the capability to send (in EDUs containing CCSDS telemetry packets) simulated recorded AM-1 spacecraft and instrument housekeeping telemetry packets.
- The SSIM has the capability to send (in EDUs containing CCSDS telemetry packets) simulated AM-1 SCC, CTIU, and instrument microprocessor memory dump telemetry.

3.9.2 Software Development and Validation Facility

The EOS ground support includes one SDVF. The SDVF is located at the AM-1 vendor facility in Valley Forge, Pennsylvania, and contains flight software development tools and flight software diagnostic tools.

3.9.2.1 SDVF Description

The SDVF generates and tests flight software updates and provides flight software loads to the EOC for uplink to the EOS spacecraft.

3.9.2.2 SDVF Design Drivers

SDVF design drivers include

- Maintenance of flight software validation database
- AM-1 flight loads and updates from SDVF to EOC
- AM-1 flight software dumps from EOC to SDVF

3.9.3 Spacecraft Analysis Software

Spacecraft Analysis Software (SAS) is developed by the AM-1 spacecraft contractor to provide flight performance analysis and evaluation for the AM-1 spacecraft. These functions include analyzing spacecraft performance trends, detecting failures, and evaluating subsystem performance. The SAS is hosted on a workstation in the EOC.

The SAS functions include analyzing spacecraft performance trends, detecting incipient failures, and evaluating subsystem performance.

The analysis software provides anomaly resolution support to the EOS Flight Operations Team (FOT) by performing calibrations, analyzing failures, evaluating solutions, validating procedures, reconstructing and simulating failure scenarios, and supporting anomaly diagnosis and resolution.

3.9.4 Spacecraft Checkout Station

The AM-1 Spacecraft Checkout Station (SCS), developed by the AM-1 spacecraft vendor, supports AM-1 prelaunch integration and testing at the AM-1 spacecraft vendor facility in Valley Forge, PA, and at the launch site, Vandenberg Air Force Base. The SCS can be configured to support several testing configurations, from spacecraft simulation to full-up spacecraft launch site testing. The SCS can be configured to generate and provide AM-1 telecommand CLTUs to the spacecraft and receive encoded CADUs from the spacecraft. In this configuration, the testing is conducted without EOSDIS ground system (EDOS, EBnet) involvement. Optionally, the SCS also can be configured to receive CLTUs from the EOC through the EBnet/EDOS/ETS interface and forward these CLTUs to the spacecraft. The SCS also can forward AM-1 telemetry CADUs to the EOC through an EBnet/EDOS interface.